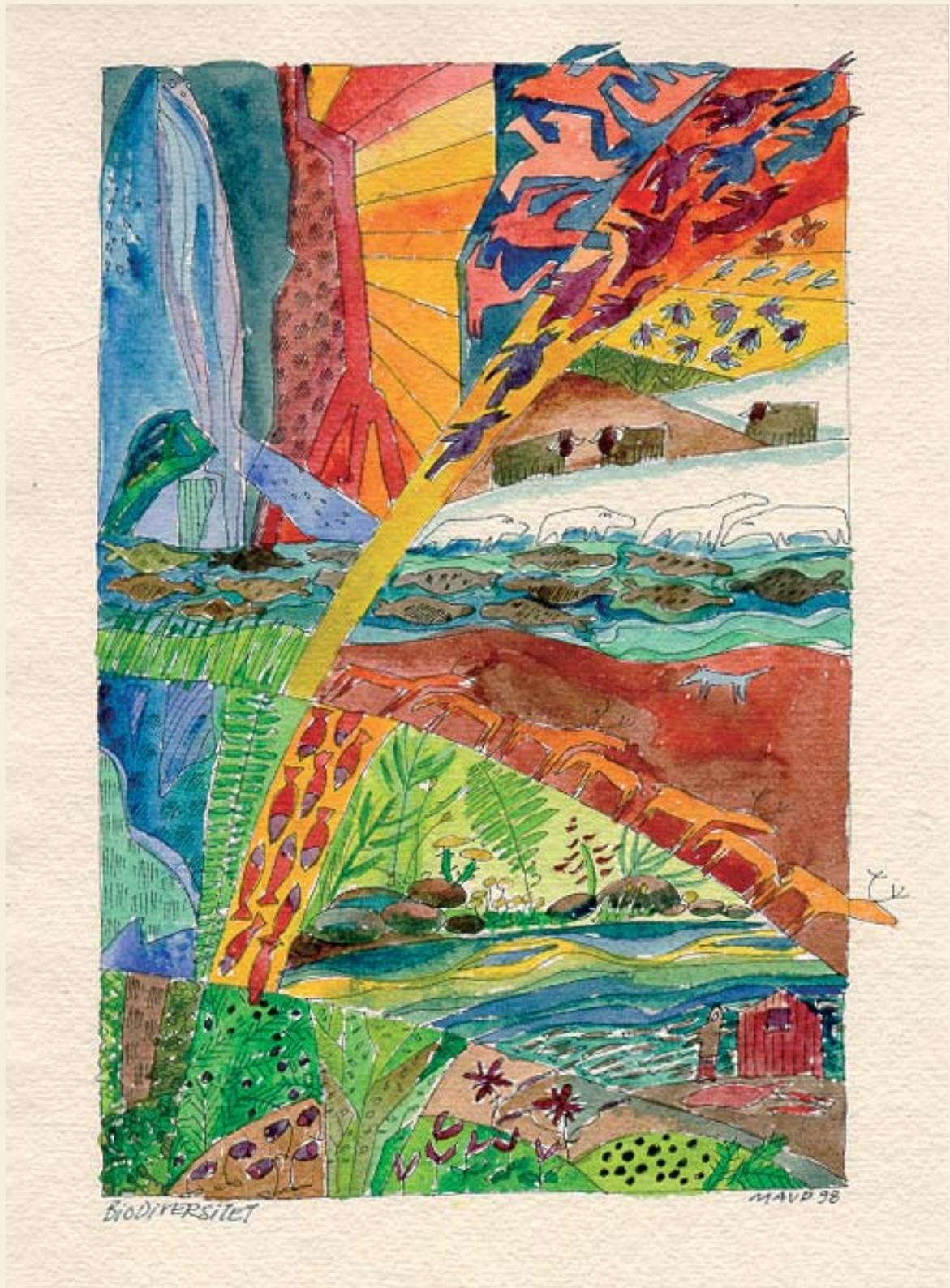


# *The Biodiversity of Greenland – a country study*



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## **Greenland Institute of Natural Resources**

Greenland Institute of Natural Resources (Pinngortitaleriffik – Grønlands Naturinstitut) is an independent research institute under the Greenland Home Rule. The institute was founded in 1995 and provides scientific background data regarding utilisation and exploitation of living resources in Greenland.

# The Biodiversity of Greenland – a country study

*Dorte Bugge Jensen & Kim Diget Christensen  
(Eds.)*



Technical Report No. 55, December 2003  
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## *Preface*

In everyday life in Greenland interest in the flora and fauna centres in particular on the relatively few species that are exploited. The discussions in the media concentrate on even fewer species - those where restrictions on exploitation have been introduced; a total of only some 50 species.

It will thus come as a surprise to most people that today we know of over 9,400 different species in Greenland.

This knowledge is a direct result of the study presented in this report. But the report can also be of importance for other areas. For schoolchildren, students and others who have to work with nature in Greenland, an overall picture – unique in the Greenlandic context – of species and ecosystems has been created. In addition the bibliography opens up for further study.

And as far as nature management is concerned, Greenland now has a unified basis for working further for the overall protection of the total biodiversity. This is Greenland's first step towards the fulfilment of the Convention on the Biological Diversity. The next task will be to draw up a strategy for how the total diversity of species and ecosystems can be protected. An attempt will be made to incorporate this in the legislative work of the coming years. In the longer term progress reports will be drawn up for the nature protection work, and these will regularly supplement the knowledge collected at present.

Right now it is a pleasure that the country study has been completed. This gives an opportunity for nature protection in the future to be viewed in a far wider context than has been the case until now.

Peter Nielsen

Head of Department  
Directorate of the Environment

## *Summary*

This is a slightly updated translation of a report originally published in Danish in 1999. The Greenlandic country study was initiated on the basis of recommendations given in the Convention on Biological Diversity signed in Rio, Brazil, in 1992.

The country study will form the basis for Greenland's strategy and action plan for the preservation and utilisation of biodiversity, which is under preparation and also function as a reference work for policy-makers, administrators, teachers and other interested parties. It includes 17 tables and 45 maps as well as databases of certain taxonomic groups.

Biodiversity is partly determined by the various physical conditions that prevail, and the ability of animals, plants and micro-organisms to spread and adapt to new conditions. The situation of Greenland in the arctic climatic zones (Map 1) is crucial for the physical conditions to which the living organisms are exposed. The fact that almost all life in the country went extinct during the last ice age, and later had to re-colonise, is of great importance to the species found in the various ecosystems today.

Both on the land and in the sea there are areas characterised by a relatively high primary production compared with other areas – examples are birch forests in South Greenland and areas close to the ice edge. This makes these areas attractive to a number of species that live in close association with them or visit them at particular times of the year. Other areas, for example the polar desert and salt lakes, are poorer in species and only support organisms that are specially adapted to the given physical framework. In the review of the diversity of ecosystems emphasis has been given to areas that are particularly vulnerable to disturbance. Particularly vulnerable terrestrial areas include birch forests, hot springs, moulting areas for geese and calving areas for caribou and musk-ox (Maps 15, 16, 9, 11 and 13 respectively). In the coastal areas there are vulnerable areas with colonies of breeding seabirds, moulting king eiders and haul-out sites for walrus and harbour seal (Maps 19, 20, 21 and 22 respectively).

During the biodiversity assessment some 9,400 species have been recorded (Table 3). This figure only includes the species dealt with in the study, so the true number of species is higher. As in other regions in the Northern Hemisphere, the diversity of species decreases from the southern part of Greenland towards the more northern areas. The distribution of the species and their presence in the Greenlandic waters are conditioned by the sea currents, which determine the sea temperature, salinity and the extent of the sea ice. Among the most species-rich groups are marine invertebrates, limnic phytoplankton and terrestrial fungi, lichens and arthropods (Table 17, 15, 4, 5, 12 and 13 respectively). Only a few endemic species have been registered (algae, vascular plants and a single water mite). Among the birds there are a few sub-species that breed only in Greenland, but winter in other places.

The utilisation of living resources is of fundamental importance to the Greenlandic economy and culture, since fishing is the main occupation, while hunting has direct or indirect significance for about 20% of the human population (Map 4). Commercial utilisation is concentrated today on just a few species such as halibut and deep-sea shrimp (Maps 41, 42 and 43), while the hunters and private households utilise several species of sea and land mammals as well as bird and fish. A total of 25 utilised species are reviewed. An account is given of the species' distribution, hunting methods, use of the species, the regulation of the exploitation, the catch sizes and the state of stock, including whether the utilisation is sustainable.

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# 1. *Introduction to the nationwide study of Greenland*

## 1.1. *The Convention on Biological Diversity*

At the United Nations Conference on Environment and Development in Rio, Brazil 1992, 155 countries, including Denmark, signed the Convention on Biological Diversity. Greenland, as part of the Kingdom of Denmark, accepted the convention unconditionally and has thus committed itself, along with the other signatories, to preserve and manage biodiversity in a sustainable manner.

The chief purpose of the Biodiversity Convention is the preservation of biological diversity and the sustainable use of its components, as well as a fair and equal distribution of benefits gained from the use of genetic resources (Article 1, Anon., 1994a).

The concept of biological diversity, or biodiversity, is defined as the diversity of living organisms in all environments, both terrestrial and aquatic, as well as the ecological systems that they are a part of. Biodiversity includes the variation within and between species and ecosystems (Article 2, Anon., 1994a).

Biodiversity includes the variation among all living organisms and can generally be defined on three levels:

*Species diversity* encompasses how many species are found in a given geographical area. A species is most often defined as a group of organisms that are capable of breeding and bearing fertile offspring under natural conditions.

*Genetic diversity* encompasses the variation in genetic material within a single species. Genetic diversity makes it possible for a species to evolve and to adapt to changes in the surrounding environment.

*Ecosystem diversity* encompasses the variation within the interactions living organisms have with each other and with their physical surroundings.

Another of the convention's main points is the *sustainable use of biodiversity*. The term *sustainable use* entails the use of biodiversity in a manner that does not lead to a long-term decline in biodiversity and thus, preserves the potential to meet the needs of present and future generations (Article 2, Anon., 1994a). In practice this means the sustainable use of biological resources. According to the Biodiversity Convention, *biological resources* include genetic resources, organisms or parts of organisms and populations or any other biotic component of an ecosystem that have an actual or potential use or value for humanity (Article 2, Anon., 1994a).

Article 6 of the Biodiversity Convention orders participating countries to develop national strategies and action plans for the preservation and use of biodiversity (Anon., 1994a).

A global environmental action program called *Agenda 21* was also adopted at the conference in Rio. One of the recommendations made in Agenda 21 is that nationwide studies should be the basis of the development of a country's national strategies and action plans.

## **1.2. *The nationwide study of Greenland***

The purpose of the nationwide study of Greenland is to create a foundation for the country's strategy and action plan for the preservation and use of its biodiversity. It is also envisioned that the nationwide study will be used as reference material for politicians, managers, teachers and other interested individuals.

Literature and knowledge regarding Greenland's environment is very scattered and a lot of the information is located outside the country. An attempt has therefore been made to gather as much information as possible and to present it in a manageable format. Information and assistance have been received from a long list of experts to meet this goal. Contributions of approximately 20 authors have been compiled and edited to produce this report. Thematic maps (GIS maps) are provided that can be used in the management of Greenland's biodiversity and in the dissemination of information regarding its environment. In addition to this, species databases have been compiled for some of the taxonomic groups.

The report includes a short introduction followed by three chapters on, respectively, ecosystem diversity, species diversity and the use and protection of biological resources. The content of each chapter is a result of the type of information that was available for each subject area and the type of expert assistance that could be accessed. This means that some of the chapters are more detailed than others. A comprehensive list of the literature cited is provided at the end of the four chapters. The structure of the report has been chosen with the intention of making it easy to precisely access the information of interest and there may therefore be instances where repetitions occur.

## **1.3. *Introduction to Greenland***

### **1.3.1. *Geography and climate***

Greenland is the world's largest island. The country stretches from Nunap Isua in the south (59.46° N) to Odaap Qeqertaa (83.40° N), which is the northernmost territory in the world. The country is intersected by the Arctic Circle (66.33° N), north of which one experiences days of the year with darkness and days of the year with midnight sun. The further north one goes, the longer the period of darkness and of midnight sun.

The total area of Greenland is 2,175,600 km<sup>2</sup>. Only about 15% of the country is free of ice, the rest is covered by the world's second largest ice cap, the Greenland Ice Cap. It contains about 9% of the Earth's fresh water and is approximately 3,500 m thick at its thickest point. In some places along the coast, mountain peaks protrude through the surface of the ice and form islands of land called nunataks. Where glaciers reach the sea, icebergs break off and are carried away by ocean currents. Greenland's approximately 40,000 km long coastline has a countless number of large and small islands and fjords.

Greenland is located in the Arctic. This means that the average summer temperature never rises above 10° C, that there is permafrost, where only the top soil layers manage to thaw in

the summertime, that the country has very little precipitation and that there are no true forests, just single trees and scrub in South Greenland that reach the height of a man. The country can be divided into climatic zones comprising the Low Arctic, the Arctic, and the High Arctic (map 1). Northern Greenland, where some areas are covered by Arctic desert, has the least amount of precipitation. South Greenland receives more precipitation and is fertile enough to support limited agriculture.

Several ocean current systems meet in the waters surrounding Greenland (map 2). They influence the sea's temperature and salinity, among other things, and thus the distribution of marine organisms. Likewise, the ocean currents influence the distribution of sea ice. The presence of sea ice means that areas from Qeqertarsuup Tunua and northward, as well as on the east coast, can only be reached by boat for a few months during the summer. In the western part of Greenland, from Paamiut County to Sisimiut County, there is a so-called open water area where only the fjords and coastal waters occasionally freeze during the winter.

### ***1.3.2. Inhabitants***

Greenland is divided into 18 counties, each with its own capital, and a total of 59 settlements (map 3). In 1996 there were approximately 56,000 people living in Greenland, 80% of which resided in cities and about 20% in settlements. The majority of the population lives in western Greenland in Paamiut, Nuuk, Maniitsoq and Sisimiut Counties. The southern counties and the sealing and whaling regions located in Uummannaq, Upernavik, Qaanaaq as well as Tasiilaq/Ammassalik and Ittoqqortoormiit Counties, are the least populated.

### ***1.3.3. Economy***

Fishing is the principal occupation in Greenland and is estimated to employ around 2,500 individuals directly and another 3,000 in the fishing industry. In addition to this, a number of people have occupations somehow connected with the fishery. While hunting has a direct or indirect influence on approximately 20% of the population, it is the principal occupation in Qaanaaq, Upernavik, Uummannaq, Tasiilaq/Ammassalik and Ittoqqortoormiit Counties (map 4). Sheep and reindeer are farmed in South Greenland (map 5). It is expected that tourism and raw materials extraction will become leading industries supplementing the fisheries.



## 2. *Ecosystem diversity*

An ecosystem is composed of the dynamic interplay between non-living (abiotic) and living (biotic) factors. Abiotic factors, such as temperature, precipitation and nutrients, create the setting within which different animals, plants and microorganisms can interact with each other. Ecosystem boundaries can be drawn at many levels, thus causing an ecosystem to have a greater or lesser complexity dependent upon how boundaries are chosen.

Ecosystem diversity is, among other things, dependent upon prevailing physical conditions and the ability of animals, plants and microorganisms to spread and to adapt to new conditions. Greenland's position in the Arctic climate zone (map 1) is a decisive factor for the physical conditions living organisms are exposed to. The fact that almost all life in the country was exterminated during the last ice age and since then has had to re-colonize the area, has had a great influence on the types of organisms that can be found in the different ecosystems today. In general, the organisms that are part of Greenland's ecosystems are adapted to periods of constant darkness and constant light, to periods with a limited amount of nutrients available and to periods of very low temperature. The conditions are of course different dependent upon what type of environment is being considered.

There are areas both on land and at sea that are characterized by a relatively high level of primary production in comparison to other areas, such as birch forest and ice edges. This makes these areas attractive for the many organisms that are permanently associated with them or that seek them out at specific times of the year. Other areas, for example, polar deserts and saline lakes, have fewer species and only support organisms that are specifically adapted to the given physical conditions.

Certain areas are particularly vulnerable to disturbance. Particularly vulnerable terrestrial areas include birch forests, hot springs, geese moulting areas and caribou and muskox calving areas. Coastal regions have vulnerable areas with colony nesting marine birds, moulting king and common eiders and haul-outs for walruses and harbor seals.

In the following sections, the discussion of ecosystem diversity is approached by first mentioning the physical factors that prevail in the given environment. The general ecology of the environment is then discussed and finally, a number of habitats in the environment are mentioned with a focus on those that are particularly vulnerable.

Although cyanobacteria no longer are classified as algae, they are described as such and referred to as 'blue-green algae' in the sections that follow in this report.

## 2.1. *Terrestrial ecosystem diversity*

### 2.1.1. *Landscapes and landscape formation*

Greenland has the longest north-south stretch of landmass in the Arctic. This results in a wide range of variation in physical conditions, geology, soil, climate and terrain and therefore, a diversity of living conditions for terrestrial organisms. The most striking feature is that only 15% of the country is ice-free, while the rest is covered by the Greenland Ice Cap. The largest ice-free land areas can be found in Peary Land in Avanersuaq, Jameson Land by Ittoqqortoormiit and in the backcountry by Sisimiut. The highest mountains are located along the coasts and in some areas they protrude from the Ice Cap to form islands of land in the ice. These islands are termed *nunataks*. Nunataks have protruded from the ice during several ice ages and possibly functioned as refuges for plants and animals during the last ice age (Böcher, 1981).

The landscape was formed, and continues to be formed, by the effects of ice on its surface. Glaciers have cut through the landscape and created valleys, which often end in fjords and wet areas with lakes, mires and bogs. When the ice retreats, deposits of rock, clay, gravel, sand and moraine are left behind, which form hills, embankments and dams for lakes. The exposed landscape is also affected by water, wind and frost. When large amounts of meltwater are released in the spring, water is supplied to existing lakes and streams and new freshwater wet areas are created. Meltwater erodes the bedrock, which is also degraded by the effects of wind and frost. These are the beginnings of soil formation, which is further aided by rock degrading lichens. Actual soil formation starts when the eroded bedrock is supplied with organic matter broken down by microorganisms (Stonehouse, 1989a).

### 2.1.2. *Soil conditions*

Permafrost occurs throughout Greenland in continuous, discontinuous and sporadic patterns as shown on map 6. In North Greenland, the permafrost layer can reach a thickness of 500 m. The layer gets thinner towards the south and due to heat given off by the water, disappears near the sea, lakes and streams. The landscape's height above sea level is also a determining factor for the thickness of the permafrost layer (Weidick, 1981).

In the summer, only the top layer of soil, the so-called *active layer*, thaws. The thickness of the active layer is dependent upon latitude and local conditions. In North Greenland's High Arctic, the active layer is only a few centimeters thick, while in South Greenland it can be a couple of meters thick. On south facing, sunny slopes the soil will thaw at greater depths than in shaded areas. The soil formation processes, where bacteria, fungi and detritus feeders break down organic matter, are limited to the active layer. Because of this, there is a big difference in soil composition between South and North Greenland.

Permafrost inhibits precipitation and meltwater from seeping down into the deeper soil layers, thus causing the active layer to become waterlogged. *Solifluction soil* can form in a sloping terrain when the active layer is water logged and begins to flow due to the terrain's incline. This then forms *polygonal patterned ground* in the terrain. The soil's stability is a determining factor for which plant species can become established (Stonehouse, 1989a).

### 2.1.3. *Primary production and decomposition of dead organic matter*

Primary production is the basis for all other life in an ecosystem. On land, algae, lichens, mosses and vascular plants are the primary producers. With the use of light from the sun and the absorption of carbon dioxide (CO<sub>2</sub>) and nutrients, oxygen (O<sub>2</sub>) and carbohydrate chains are produced, which can be utilized by plant eaters (herbivores). Among other things, a plant's production is dependent upon the amount of solar irradiation and uptake of water and nutrients. Yearly photosynthetic production in Greenland is low in comparison to more southerly areas. Due to the long dark winter, production has a greatly skewed distribution

during the year. Around mid-summer photosynthesis reaches considerable heights. The ability of different plant species to photosynthesize varies, thus creating a difference in total photosynthetic production among species (Eckardt, 1987).

The ground's nutrient content, and thereby a plant's growing conditions, varies with terrain and the history of the landscape. Places where the ice has recently exposed the ground are barren with only a few thrifty pioneer species. However, the inner fjords in South Greenland, for example, which have been free of ice for millennia, are fertile and are primers for scrub and woodland growth. Hilltops are often nutrient poor, while areas at the base can be especially rich in nutrients (Eckardt, 1987). When the ground thaws, nutrients are released into the stratum above the permafrost. However, the humus layer's nutrients are tightly bound and only released with the decomposition of the humus.

Dead organic matter from both plants and animals is decomposed in the soil. Decomposition is slow because of low temperatures and the presence of frost in the active part of the soil for a large part of the year. Heterotrophic bacteria and fungi can absorb free organic molecules directly across the surface, while soil dwelling invertebrates eat dead organic matter. Together, the activities of worms and plant roots aerate and mix the soil. The most important groups of decomposers (*saprotrophs*) are earthworms, enchytraeid worms (Oligochaeta), roundworms (Nematoda), beetle mites (Oribatida), springtails (Collembola) and various insect larvae.

#### **2.1.4. Plant communities**

Greenland's range from north to south of more than 2,600 km and from oceanic outer coastal areas to continental inland areas, creates a large amount of variation in species composition and distribution of plant communities (map 7). One of the most important determining factors for plant distribution, besides summer temperatures, is snow cover. Plants are more or less covered by snow for 9 to 11 months out of the year. The thickness and duration of the snow cover influences the length of the growing season and the amount of water released to the plants during the course of the summer. Generally speaking, the snow cover increases from inland areas to coastal areas and from North to South Greenland.

The diversity of terrestrial habitats can be illustrated by describing the plant communities that occur in different geographical regions. All plant species require specific growing conditions and will occur only where these conditions are met. Because big differences in soil conditions occur, even in small areas, with respect to mineral nutrients, water content and microclimate, plants are not distributed equally in the terrain. Instead, they are grouped in different types of plant communities according to ecological conditions.

Arctic vegetation is divided into a number of plant communities according to species composition, life strategies, degree of vegetation cover and relationship to physical parameters, such as soil texture and water content, snow cover and slope and aspect of the terrain. Species composition changes from south to north and from coastal to inland regions. Below is a description of the various plant communities. An overview of the plant communities is given in table 1.

##### **2.1.4.1. Heath**

Vegetation dominated by dwarf shrubs, i.e. woody plants less than half a meter tall, is termed *heath*. Heath is the most common vegetation type, especially in Low Arctic Greenland. In the southern part of Greenland northern willow (*Salix glauca*) and bog bilberry (*Vaccinium uliginosum* ssp. *microphyllum*) are widespread, while other dwarf shrub species have a more limited distribution due to their narrower ecological niche in terms of soil and climate demands. Crowberry (*Empetrum*) dominates the coastal areas, while dwarf birch (*Betula nana*) and rock cranberry (*Vaccinium vitis-idaea* ssp. *minus*) assume the dominant role in the

**Table 1.** Overview of the most important plant communities in Greenland. For each community type the following information is provided: some of the characteristic species; distribution in Greenland; ecological demands, including the relationship to the soil's water content and acidity. Compiled by Christian Bay (1997).

Plant community	Characteristic species	Distribution in Greenland	Ecological demands	Soil water content and acidity
<b>Subarctic heath</b>				
Crowberry heath	Crowberry ( <i>Empetrum nigrum</i> ssp. <i>hermaphroditum</i> ), Alpine club moss ( <i>Diphasiastrum alpinum</i> ), Mountain heath ( <i>Phyllodoce coerulea</i> )	Low Arctic, coastal	Heavy, stable snow cover	Moist, acidic-neutral
Bog bilberry heath	Bog bilberry ( <i>Vaccinium uliginosum</i> ), Lapland lousewort ( <i>Pedicularis lapponica</i> ), Stiff clubmoss ( <i>Lycopodium annotinum</i> )	Low Arctic	Moderate snow cover	Moist, acidic-neutral
Birch heath	Dwarf birch ( <i>Betula nana</i> ), Labrador-tea ( <i>Ledum</i> sp.), Rock cranberry ( <i>Vaccinium vitis-idaea</i> ssp. <i>minus</i> )	Low Arctic, inland	Light snow cover; warm summers	Moist-dry, acidic-neutral
<b>Middle and High Arctic heath</b>				
White Arctic bell-heather heath	White Arctic bell-heather ( <i>Cassiope tetragona</i> ), Fur club moss ( <i>Huperzia selago</i> ), and <i>Pedicularis</i> spp.	Middle Arctic	Moderate snow cover	Moist, acidic-neutral
Mountain avens heath	Mountain avens species ( <i>Dryas</i> sp.), Lapland rose-bay ( <i>Rhododendron lapponicum</i> )	Middle and High Arctic, inland	Light, unstable snow cover	Moist-dry, neutral-alkaline
<b>Scrub</b>				
Willow scrub	Northern willow ( <i>Salix glauca</i> ), Oak fern ( <i>Gymnocarpium dryopteris</i> ), Bluejoint reedgrass ( <i>Calamagrostis langsdorfii</i> )	Low Arctic	Heavy snow cover; snow free early; protected places	Wet-moist, acidic-alkaline
Alder scrub	Green alder ( <i>Alnus crispa</i> ), willow-scrub species ( <i>Salix</i> sp.)	Inland in Southwest Greenland	Heavy snow cover; protected slopes	Wet-moist
<b>Forest</b>				
Birch forest	Mountain birch ( <i>Betula pubescens</i> ), Mountain ash ( <i>Sorbus groenlandica</i> )	A few inland areas in South Greenland	Heavy snow cover; valleys that are warm in the summertime	Wet
<b>Herb-slope</b>				
Herb-slope	Small white orchid ( <i>Leucorchis albida</i> ), Alpine speedwell ( <i>Veronica alpina</i> ), Alpine cinquefoil ( <i>Potentilla crantzii</i> ), Hawkweed ( <i>Hieracium</i> sp.) and dandelions ( <i>Taraxacum</i> sp.)	Low Arctic	Heavy snow cover; snow free early; south facing slopes	Wet-moist
<b>Snow-bed</b>				
Early snow-bed	Dwarf willow ( <i>Salix herbacea</i> ), Moss heather ( <i>Harrimanella hypnoides</i> ), Procumbent sibbaldia ( <i>Sibbaldia procumbens</i> )	Low Arctic	Heavy snow cover; short growing season	Wet-moist
Late snow-bed	Spiked snow-grass ( <i>Phippsia algida</i> ), Alpine brook saxifrage ( <i>Saxifraga hyperborea</i> ), Two-parted sedge ( <i>Carex lachenalii</i> )	Middle and High Arctic	Very short growing season	Wet
<b>Mire</b>				
Oligotrophic mire	Tall cottongrass ( <i>Eriophorum angustifolium</i> ), Arctic cottongrass ( <i>Eriophorum scheuchzeri</i> ), Loose-flower alpine sedge ( <i>Carex rariflora</i> ), Russet sedge ( <i>Carex saxatilis</i> )	Low and Middle Arctic	Substrate continuously wet	Wet, acidic
Eutrophic mire	Scorched alpine-sedge ( <i>Carex atrofusca</i> ), Simple kobresia ( <i>Kobresia simpliciuscula</i> ), Three-flowered rush ( <i>Juncus triglumis</i> )	Middle Arctic	Substrate continuously wet	Wet, alkaline

Table 1. (continued)

Plant community	Characteristic species	Distribution in Greenland	Ecological demands	Soil water content and acidity
<b>Mire (continued)</b>				
	Tundra sedge ( <i>Carex stans</i> )	High Arctic	Substrate continuously wet	Wet, acidic
<b>Grassland</b>				
Grassland	Common hairgrass ( <i>Deschampsia flexuosa</i> ), Alpine lady's mantle ( <i>Alchemilla alpina</i> ), <i>Agrostis stricta</i>	Low Arctic	Moderate snow cover; long growing season	Moist
<b>Steppe</b>				
Steppe	Weak Arctic sedge ( <i>Carex supina</i> ), the small-reed <i>Calamagrotis purpurascens</i> , Alpine sedge ( <i>Kobresia myosuroides</i> )	Inland in Low and Middle Arctic	Light snow cover; snow free early; long growing season	Dry-extremely dry
<b>Fell-field</b>				
Dry type	Fries spike sedge ( <i>Carex nardina</i> ), Arctic poppy ( <i>Papaver raticatum</i> ), Glaucous spear-grass ( <i>Poa glauca</i> )	Low and High Arctic	No snow or light snow cover	Dry
Wet type	Vahl's Arctic saltmarsh grass ( <i>Colpodium vahlinum</i> ), Spiked snow-grass ( <i>Phippsia algida</i> ), snow pearlwort ( <i>Sagina intermedia</i> ), Polar stoloniferous saxifrage ( <i>Saxifraga platysepala</i> )	Middle and High Arctic	Heavy snow cover; snow free late	Wet
<b>Arctic desert</b>				
Arctic desert	The small-reed <i>Calamagrotis purpurascens</i> , Bulbous saxifrage ( <i>Saxifraga cernua</i> ), Alpine Chickweed ( <i>Cerastium arcticum</i> )	Only a narrow coastal zone in North Greenland	Low summer temperatures; moderate snow cover; short growing season	Wet-moist
<b>Lake</b>				
Low Arctic, nutrient-poor lakes	Burreed ( <i>Sparganium hyperboreum</i> ), alternate flowered milfoil ( <i>Myriophyllum alterniflorum</i> ), Spiny spore quillwort ( <i>Isoetes echinospora</i> )	Low Arctic		Alkaline
Low Arctic, nutrient-rich lakes	Slender pondweed ( <i>Potamogeton filiformis</i> ), Eurasian watermilfoil ( <i>Myriophyllum spicatum</i> )	Low Arctic		Acidic
High Arctic, nutrient-rich lakes	Far-northern buttercup ( <i>Ranunculus hyperboreus</i> )	High Arctic		Alkaline

warmer, arid inland. Several herbs, mosses and lichens are associated with the dwarf shrubs, which are 10-30 cm tall.

In the Middle Arctic, white Arctic bell-heather (*Cassiope tetragona*) is completely dominant in places with a protective snow cover every winter. *Mountain avens heaths* (*Dryas*) however, are found in more wind exposed places in terrain with a thin, less stable snow cover. Tundra willow (*Salix arctica*) is present in nearly all plant communities in the High Arctic, but especially in moist or slightly dry soils. In Northeast Greenland, it is the characteristic plant for a special type of snow-bed with a medium duration snow cover, which thus far has only been found in this region.

#### 2.1.4.2. Scrub

Meter-high *scrub* of northern willow (*Salix glauca*) is found in the Low Arctic along streams and on protected slopes with heavy snow cover during the winter. Inland, in Southwest Greenland, green alder (*Alnus crispa*) makes up the scrub. Like the tundra willow, northern willow can grow in almost all plant communities, from dry slopes to mounds in wet mires.

#### 2.1.4.3. Forest

Together with scrub, forest belongs to the most productive terrestrial habitats. *Birch forest* is only found in the summer-warm inland areas in South Greenland. These areas contain several boreal species not found elsewhere in Greenland. Trees of mountain birch (*Betula pubescens*) can reach heights of up to 7 meters. Closely associated with mountain birch are several fungi such as large mycorrhiza forming fungi and saprophytic fungi. Scrub forests with mountain birch probably contain more than 200 basidiomycete species, of which half are not found anywhere else in Greenland. Birch and willow scrubs are also rich in lichens.

Qinngua Valley in South Greenland has the most developed subarctic birch forest. Feilberg and Folving (1990) have mapped the vegetation in the region. Birch forest is sensitive to sheep grazing since mountain birch, which is consumed by sheep, stops growing when grazed (Fredskild & Ødum, 1990). Sheep grazing is detrimental not only to birches, but also to the many species that are associated with birch forest and scrub.

#### 2.1.4.4. Snow-bed

The *snow-bed* plant community is known only from Arctic regions and mountainous regions in other plant ecotypes. Snow is not distributed evenly in the terrain; instead it accumulates in areas where there is shelter from the wind. Since the prevailing wind direction is fairly constant, snowdrifts lie in the same place year after year; in Low Arctic Greenland this is most often on north facing slopes, while in the Middle and High Arctic parts of Greenland, this is most often on south facing slopes. Plants have rather different demands for and tolerances of the thickness and duration of the snow cover. Many species cannot complete their life cycle if the growing season is shortened due to a late snowmelt. Woody plants, with the exception of dwarf willow (*Salix herbacea*) and moss heather (*Harrimanella hypnoides*), cannot survive in snow-beds. Plant species found in snow-beds are adapted to the short growing season and favor the stable winter temperatures and humidity, as well as the water quantities released gradually as the snow melts during the summer. A differentiation is made between *early* and *late snow-beds*. The early snow-beds have a greater diversity of species and many of the herb-slope species occur here. Late snow-free snow-beds, where mosses are the dominant plant group, have a growing season of only a few weeks and in some years, do not manage to become snow-free. Spiked snow-grass (*Phippisia algida*) is a characteristic species for this plant community.

#### 2.1.4.5. Herb-slope

Herb-slopes, like snow-beds, have a thick and stable snow cover during the winter. In contrast to snow-beds however, the growing season is only shortened by a small amount since herb-slopes primarily occur on south facing slopes with a high amount of solar radiation and thus, an early snow melt. Because of the large amounts of snow, the ground is moist throughout the growing season. Herb-slopes are dominated by broad-leaved, lush herbs and ferns and have the greatest number of species among Arctic plant communities. In contrast to other plant communities, all aboveground biomass in wet meadows dies back every winter. Many of the southern plant species are found in these communities. The northernmost herb-slopes at the transition between Low and Middle Arctic are home to species that are found in other types of plant communities towards the south. Characteristic to this community type are several species of fern and two of Greenland's orchid species. Northern willow (*Salix glauca*) is the only woody plant that grows on herb-slopes. In those places where it is most prevalent, it forms transitions to actual willow scrub.

#### 2.1.4.6. Mire

*Mires* are sedge or grass dominated plant communities on wet or moist substrates that do not dry out during the growing season. Mires are particularly found in connection with water-courses and lakes, but also in depressions in heaths. One differentiates between oligotrophic mires on acidic soil types and eutrophic mires on alkaline basalt or sediment soils. Mires

predominantly occur in the southern and northern part of Greenland. A thick, more or less continuous layer of moss is found on stable substrates. Tundra sedge (*Carex stans*) dominates High Arctic mires, while loose-flower alpine sedge (*Carex rariflora*) and russet sedge (*Carex saxatilis*) dominate Low Arctic regions. Arctic cottongrass (*Eriophorum scheuchzeri*) is found in both Low Arctic and High Arctic mires, but is most common in the Low Arctic.

#### 2.1.4.7. Grassland and steppe

Dry grass and sedge dominated community types are termed *grassland* and *steppe*. Inland areas in central West and East Greenland contain steppes that are associated with south facing slopes and flat valley bottoms with a thin snow cover. The growing season starts very early. However, the ground dries out completely during the summer causing plants to wither and thus, to be unable to utilize the last part of the growing season. Grasslands have a larger composition of broad-leaved herbs and are found on wetter soils both in coastal and inland regions with a heavier snow cover.

#### 2.1.4.8. Fell fields

All plant communities composed of a very scattered and sparse plant cover are termed *fell fields*, which include both wet solifluction soil where the permafrost prevents the establishment of roots and wind exposed areas with dry soil. Due to extreme ecological differences, distinctive plant species appear in the various types. Solifluction soil is most common in the High Arctic, where only the very top layers of the ground thaw in the summer, and only a small number of species can cope with the constant creeping of soil in the root zone. Polar stoloniferous saxifrage (*Saxifraga platysepala*), snow pearlwort (*Sagina intermedia*) and Vahl's Arctic saltmarsh grass (*Colpodium vahlinum*) are characteristic in such areas. Vahl's Arctic saltmarsh grass has long, curled roots that when pulled, can give without breaking. In the drier part of the fell field in northern Greenland, cushioned meadow-grass (*Poa abbreviata*), alpine sedge (*Kobresia myosuroides*) and the small-reed *Calamagrotis purpurascens* are found. Polar deserts, characterized by short, cold and foggy summers, are found in the outer coastal regions of North Greenland. These areas are species poor and devoid of woody plants and sedges. Lichens and mosses are those plant groups that best can cope in polar deserts. The term polar desert has previously also been used to describe the very low precipitation regions in the interior of North Greenland. However, here it is not the low summer temperatures, but the lack of precipitation, that is the limiting factor for plant growth.

#### 2.1.4.9. Hot springs

A unique and rare plant community is found in connection with hot springs. The ground around hot springs thaws early in the spring because of the surfacing of water with a constant temperature above 0°C. The growing season is thereby extended and growing conditions are more reminiscent of those occurring in more southerly areas. Species richness is often far greater than in the surrounding terrain. Several Low Arctic species have their northernmost occurrences by hot springs, both in West and East Greenland (Feilberg, 1985). See section 2.2.3.4 for a more detailed description of the organisms associated with hot springs.

In comparison to other Arctic regions, Greenland is missing an otherwise common Arctic plant community, the wet tundra. Wet tundra covers large areas in Arctic coastal regions along the Arctic Ocean in both North America and Russia. In addition, "tussock tundra", which is very common in North America and Russia, is also absent from Greenland. This community type is dominated by sheathed cotton-grass (*Eriophorum vaginatum*), a species that is nearly absent in Greenland. However, a subspecies of sheathed cotton-grass, hare's tail (*Eriophorum spissum*, synonymous with: *Eriophorum vaginatum* ssp. *spissum*), is found in an area by Paamuit in South Greenland.

### 2.1.5. Floristic provinces

Greenland is divided into a number of floristic provinces based on similarities among vascular plant distribution patterns. These provinces are further divided into floristic districts as indicated on map 8 (Böcher *et al.*, 1959). These divisions have been revised based on information gathered over the past decades (Bay, 1997; Feilberg, 1984a; Fredskild, 1996a). The most marked changes are: 1) the division of each of the North and South Greenland provinces into two districts; 2) the new demarcation of districts at the transition from Low to Middle Arctic areas in West Greenland; 3) the splitting of districts in Northwest and Northeast Greenland and 4) the expansion of Low Arctic inland regions in West and East Greenland.

### 2.1.6. Terrestrial arthropods

#### 2.1.6.1. Detritus feeders

Terrestrial and freshwater arthropods (Arthropoda) feed primarily on dead organic matter (*saprotrophs*) on the bottom of fresh water bodies and in moist soil. Many are probably omnivorous (*polytrophs*) since they consume large amounts of bacteria, fungal hyphae, algae cells and protozoa that, along with the dead matter, probably comprise the most important part of their diet. Important saprotrophic groups among the arthropods are beetle mites (Oribatida), springtails (Collembola) and many insect larvae (midges, crane-flies and other mosquito and fly families). Information about the life cycles, diets, density and so forth, of individual species is still too limited to evaluate the production related role of insects in Arctic ecosystems. However, one can assume that small organisms living in Arctic soils are important in the decomposition of dead organic matter, as are soil dwellers elsewhere, primarily by breaking it down to the point that bacteria and fungi can decompose it completely. The many carrion feeding larvae in soil and fresh water are without a doubt also very important for nutrient conversion in the decomposition food net (Ryan, 1981). The many midge species, which occur in very dense populations, are probably the most important in relation to production. As larvae, they feed on decaying plant remains. These remains are thereby converted to 'insect tissue', which is of invaluable importance to Arctic land-living birds and to the large summer populations of wading birds in the High Arctic. Even species that are primarily vegetarian, such as snow buntings (*Plectrophenax nivalis*) and Lapland longspurs (*Calcarius lapponicus*), feed their young mainly with insects and spiders (Kampp & Kristensen, 1981). Mosquito larvae and pupae are a crucial food for Arctic char (*Salvelinus alpinus*), while insects in general are a substantial part of the Arctic fox's (*Alopex lagopus*) diet (Kevan & Danks, 1986; Birks & Penford, 1990; Bergensen, 1993).

#### 2.1.6.2. Herbivores and pollinators

A minority of arthropods are herbivores and only rarely in the High Arctic. Only a few species feed directly on the green parts of the plant (*e.g.*, butterfly larvae, saw flies, aphids and psyllids), some feed on seeds (*e.g.*, the arctic-alpine seed bug (*Nysius groenlandicus*)), and quite a few feed on roots (fly and beetle larvae). In some years, the butterfly larvae of some species are extremely abundant and become pest species on hay crops in South Greenland (*e.g.*, the cutworm moths *Eurois occulta* and *Caradrina quadrangula*; Nielsen, pers. comm.).

With the exception of a couple of species of pill beetles (Byrrhidae) and some tardigrades (Tardigrada), the voluminous mosses are almost negligible in the diet of microfauna. The same is true for the many larvae. Fungi, however, are eaten by fungus gnat larvae (Mycetophilidae). Insects do not consume more than a couple of percent of the higher plants' primary production in some regions in the Arctic. An equally small fraction of insect production passes on to insectivores (Kevan & Danks, 1986a).

Flower products however, play an important role for adult insects, which consume pollen and nectar. Nectar provides energy for an insect's energy demanding flight (especially flies, butterflies and bumblebees). Protein rich pollen is important for egg production in a number of flies and, along with nectar, for feeding bumblebee larvae.

Insects play a vital role as pollinators of flowers. It has previously been stated that Arctic flowering plants are able to reproduce without insect visits. However, it has now been shown for a large number of species that visiting insects are a prerequisite for optimal seed production (Phillip *et al.*, 1990).

#### 2.1.6.3. *Predators, parasitoids and parasites*

The omnivorous soil-saprotrophs are, as mentioned, partly viewed as predators. Actual predators are found among the insects (many flies and certain beetles), mites and spiders. Spiders are exclusively predatory, catching their prey in many different ways. Bottle fly larvae live in manure or vertebrate carcasses, but in some cases occur as skin parasites (*e.g.*, in sheep).

*Parasitoid* is the term used for insects that lay eggs in other insects, where the larvae mature and eventually kill the host. There are many Arctic parasitic wasps (Ichneumonidae, Braconidae, etc.) whose biology for the most part is unknown. Some of the larger species live in and off of butterfly larvae. Parasitic flies (Tachinidae) live in much the same way. Actual *parasites*, which parasitize on the surface of (ectoparasites) or inside (endoparasites) other animals, are found in many groups. From the Arctic region, the caribou's throat botfly (*Cephenemyia trompe*) can be mentioned. Some of the numerous ectoparasites are stationary and can only survive with the host's body heat, that is, on the body, in feathers or in fur (fleas, lice, fur and feather lice, mites). Larvae of the bottle fly *Protophormia terraenovae* can occur as parasites on wounds in sheep. Other parasites are temporary and only reside on the host during the actual consumption of blood; mosquitoes (Culicidae), black flies (Simuliidae), biting midges (Ceratopogonidae) and bed bugs (*Cimex lectularius*). Certain mites are ectoparasites on insects (*e.g.*, on bumblebees), which in some cases act as transportation devices for the mites.

#### 2.1.6.4. *Arthropod population density and production*

Only a few quantitative studies of Arctic terrestrial and freshwater arthropods and their productivity have been carried out, although almost none in Greenland. Studies in the North American Arctic and in Siberia have shown that springtails quite often occur in very large quantities in the Arctic, 0.2-1.0 million per m<sup>2</sup>, which is much greater than what has been counted further south (Danks, 1981). Mite populations are consistently smaller (up to 80,000 per m<sup>2</sup>). In lush ponds there can be somewhere around 27,000 midge larvae per m<sup>2</sup> (Danks, 1981). One square meter of steppe in Greenland can house 50-100 seed bugs (*Nysius groenlandicus*) (Böcher, 1976). However, by far the largest number of insects occur at much lower densities, such as the Arctic woolly bear caterpillar (*Gynaephora groenlandica*), with a maximum density of 0.1 per m<sup>2</sup>, even in the most favorable biotope (Ryan & Hergert, 1977).

#### 2.1.7. *Terrestrial birds and mammals*

Terrestrial food chains in Greenland are simple and short. There are typically a couple of plant species involved (mainly grasses, sedges and willows), along with an herbivore (mammal or bird) and a top predator (mammal or bird).

There are four terrestrial, herbivorous mammals: muskox; caribou; Arctic hare and Arctic lemming. In addition, geese, grouse and some duck species feed on plants. All of these are directly dependent on the plant cover, and their predators, which include wolves, foxes, ermine, jaegers, gulls, falcons, ravens and white-tailed eagles, are therefore indirectly dependent upon plants. Research within the last few decades has provided detailed information on food choice in individual herbivorous species. The results are summarized in table 2.

As is evident in the table, the preferred food items for both herbivorous mammals and birds are grass, sedge, and willow species. Grasses and sedges, which are species rich plant families, occur in all plant communities from the most barren polar desert in North Greenland to the most lush herb-slopes and scrub in South Greenland. However, they are only dominant in certain plant communities: mire, grassland, steppe and tidal meadow. Willow species,

**Table 2.** Overview of the most important food items for herbivorous, terrestrial mammals and birds during the summer and winter. The order in which the food items are listed denotes their importance during the summer and winter, in respective columns.

Species/ Study Area	Plants in the summer diet	Plants in the winter diet	Source
<b>Muskox</b>			
North Greenland	willow, sedges and grasses	sedges, grasses and willow	Klein & Bay, 1990
East Greenland	willow	grasses, sedges and willow	Thing et al., 1987
West Greenland	willow, sedges and grasses	grasses and willow	Olesen, 1989
<b>Caribou</b>			
West Greenland	grasses and sedges	grasses, sedges and lichens	Thing, 1984
<b>Arctic hare</b>			
North Greenland	grasses, sedges, herbs and willow	grasses, herbs and willow	Klein & Bay, 1994; 1995
West Greenland	woody plants, herbs and graminoids	-	Hvidt, 1994
<b>Greenland collared lemming</b>			
North Greenland	willow	willow and grasses	Klein & Bay, 1990; 1994
<b>Goose*</b>			
North Greenland	grasses and sedges	-	Klein & Bay, 1991
East Greenland	sedges and grasses	-	Madsen et al., 1985
West Greenland	grasses, arrow-grasses and mare's-tail	-	Glahder, 1999; Boertmann & Glahder, 1999
Northwest Greenland	marsh arrow-grass and mare's-tail	-	Fox & Madsen, 1981
<b>Rock ptarmigan</b>			
East Greenland	viviparous knotweed	Arctic willow and purple saxifraga	Gelting, 1937

\* In East Greenland this includes studies of pink-footed and barnacle geese, while in West Greenland the studies were on white-fronted geese.

which occur in many plant communities, are prominent in different types of heaths and snow-beds.

#### 2.1.7.1. Moulting areas for geese

Geese are among the few Greenlandic birds that have a plant diet (table 2) and therefore reside on land when they are not migrating between wintering and breeding areas. After geese have bred, they have a period of about two weeks where they moult their flight feathers and as such, are not able to fly. Important *moulting areas for geese* are shown on map 9. Since the process of changing feathers is energy demanding, molting areas must have good foraging possibilities. The areas also have to be in contact with open water so it is possible for the geese to flee if necessary. Geese are very shy in the moulting period and are vulnerable to disturbance. It is therefore important to show consideration for moulting areas and keep them free of traffic and other activities that may disturb the birds.

#### 2.1.7.2. Calving areas for caribou

Caribou (*Rangifer tarandus*) are found on the west coast with the greatest numbers occurring in regions near Nuuk, Maniitsoq and Sisimiut (map 10). Central West Greenland between the coastal mountains and the Ice Cap, where the terrain is a mixture of large hill ranges, valleys, streams, high mountain areas, lakes and a few scrub forests, has good conditions for caribou in years with plenty of summer precipitation (Vibe, 1990a).

The caribou's diet consists mainly of grasses and sedges during the summer, while in the winter, it also includes lichens (table 2; Thing, 1984). Caribou migrate to achieve optimal

foraging possibilities and caribou paths overrun the above-mentioned areas of West Greenland. It can be difficult for the caribou to dig down to their feed if a thick layer of snow or ice covers the vegetation. They then migrate to other, more favorable areas and in the winter, seek out those regions where food is most accessible, that is, where the vegetation is exposed by the wind.

In the spring and summer, when the sun begins to heat up the atmosphere, the caribou head to the mountains to seek out cool places where the heat and pestering insects are lessened. Females migrate to undisturbed areas, so-called *calving areas*, to calve (map 11). In the calving period, they are very sensitive to disturbance from human activities. When they are disturbed, they experience a conflict between staying with the calf and fleeing from danger. This can result in females, especially young females, fleeing and leaving the calf, which will perish if they do not find one another again.

#### *2.1.7.3. Calving areas for muskox*

Muskoxen (*Ovibos moschatus*) occur naturally in North and East Greenland (map 12). Muskoxen are found where the terrain alternates between highland and lowland. Their diet consists of willows, sedges and grasses in different proportions according to season (summer or winter) and depending upon whether they live in North or East Greenland (table 2). In the winter, muskox herds dig systematically in the snow to reach the vegetation (Vibe, 1990a).

Females seek out *calving areas* (map 13), where calves are born in May/June (Vibe, 1990a). As with the caribou, calving areas are especially sensitive areas, and disturbance of females and calves should be avoided. All calving areas in East Greenland, except sections of the one in Ittoqqortootmiit County, are inside national park boundaries (map 14).

#### *2.1.7.4. Predators*

The Arctic lemming is widely distributed in the northern part of the country, where it copes with the severe winters by positioning its nest and tunnels under the snow. As seen in table 2, it feeds on willow and grasses and is an important species in the High Arctic ecosystem. Lemmings function as prey for a number of predators: ermine; Arctic fox; snowy owl; jaeger; raven and at times, peregrine and gyrfalcon. The lemming population, which at times crashes, follows a cyclical pattern. This influences the ermine population such that it peaks after the number of lemmings has been at its highest, about every 1.5 years (Sittler, 1995). Other predators are also affected by the fluctuations in the lemming population. The white Arctic fox is found primarily in Northeast Greenland, where it feeds on lemmings. It seems to have much greater population fluctuations than the blue Arctic fox, which lives close to the coast where food sources probably are more stable.

The Arctic wolf was once extirpated in Greenland, but in the last 10 years has immigrated from Canada and can now be found in small numbers in North and Northeast Greenland. It is both a predator and a scavenger and can take Arctic hares, lemmings, foxes, seals on the ice and even muskox (Vibe, 1990a).

## **2.2. Limnic ecosystem diversity**

### **2.2.1. Greenland's fresh waters**

Most of Greenland's fresh water is bound in the Greenland Ice Cap. The Ice Cap is made up of 1,700,000 km<sup>2</sup> of ice, which amounts to about 9% of all the fresh water on Earth (Berthelsen *et al.*, 1989, Due & Ingerslev, 2000). A large amount of fresh water is released every spring as meltwater from the Ice Cap and from snow. Surface drainage is poor due to the permafrost layer and most of the water becomes runoff (Stonehouse, 1989b). As such, water plays a

role in building and eroding the landscape. Meltwater collects in new freshwater areas and supplies preexisting streams, lakes and ponds with water. Algae, bacteria and spores can be spread by meltwater, which also distributes nutrients to freshwater areas. The nutrient content of the water is dependent upon how much surrounding vegetation there is. The amount of organic matter present in the ground, as well as the decomposition of this organic matter, is limited. Most Arctic freshwater areas are therefore nutrient poor (oligotrophic) since they only receive a minute amount of nutrients from the meltwater (Stonehouse, 1989b). Nutrient poor waters are particularly found in gneiss areas in southern Greenland and coastal regions, while nutrient rich waters are found inland and in areas with nutrient rich soil and areas with basalt or calcium rich sedimentary rock (Fredskild, 1981).

### 2.2.2. *Freshwater ecology*

Primary production in freshwater algae is limited by the amount of nutrients available and the period of time with sufficient light. The period of time with light is limited because the water is covered by ice for a large part of the year. However, algae growth begins beneath the ice in the spring when the snow has melted and light can penetrate the ice. Algae often gather in a thin layer on the underside of the ice and are spread as the ice melts (Stonehouse, 1989b). Since many lakes are clear and nutrient poor, there are no algal blooms in the summer, as there are in warmer, nutrient-rich lakes (Fredskild, 1981).

The zooplankton is species poor in comparison to what is found further south. It includes both herbivorous and carnivorous species. The two largest groups are crustaceans (Crustacea) and rotifers (Rotifera).

Dead organic matter on the bottom is decomposed by bacteria and detritus feeding invertebrates. Beetle mites (Oribatida), springtails (Collembola) and insect larvae (of midges, crane flies and other mosquito and fly families) are among the most important groups of decomposers of organic matter in fresh water. The density of insect larvae can be very high. Up to 27,000 midge larvae per m<sup>2</sup> have been found in Arctic Canada. As one moves north, a general adaptation among Arctic insects is an increasingly larger dependence upon water and moist surroundings. The most successful insect group in the High Arctic, the midges (Chironomidae), live up to several years in different types of fresh water or moist soils.

Mosquito larvae and other insect groups are important food items for Arctic char (*Salvelinus alpinus*). Atlantic salmon (*Salmo salar*), Arctic char and three-spined sticklebacks (*Gasterosteus aculeatus*) spawn in fresh water. In some cases, char and sticklebacks live permanently in fresh water without migrating to the sea (Muus, 1990).

Quite a few birds are affiliated with fresh water for breeding and foraging (see Salomonsen, 1990). Dabbling ducks are typically freshwater birds. Harlequin ducks (*Histrionicus histrionicus*) nest on the shores of flowing streams or waterfalls and all other diving ducks, except eiders (*Somateria mollissima*), seek out fresh water to breed. Great northern divers (*Gavia immer*) usually breed on islands in freshwater lakes and travel to the coast to feed on fish, while red-throated divers (*Gavia stellata*) nest on the shores of shallow lakes. Geese nest a bit from the water and lead goslings to the lake once they have hatched. The birds live on a diet of seeds or parts of aquatic plants, insect larvae, crustaceans and fish. They add nourishment to the lakes via their excrement and loss of feathers (Stonehouse, 1989b).

### 2.2.3. *Flowing water*

There are no true rivers in Greenland as there are in Arctic Canada and Siberia. Nevertheless, the melting of glaciers and of the Ice Cap itself, leads to the country being crisscrossed by an abundance of meltwater streams and small brooks. In the winter, flowing water is covered by ice and snow and the inflow of water is either minimal or nonexistent.

### 2.2.3.1. Streams

At their origin, *streams* created by meltwater from glaciers transport a lot of sediment and are cold and murky, making them almost lifeless with just a few algae present (Røen, 1981). Further from the origin, the vegetation along streams is generally lush, depending upon the type of landscape it flows through. The vegetation consists of mosses and attached algae, which can be found as thin layers on the rocks. There are usually no aquatic plants because they cannot stay attached in the strong current and coarse substrate (Fredskild, 1981). As in all of Greenland's fresh water, midge larvae, an important food source for Arctic char, are present. Arctic char, Atlantic salmon and three-spined sticklebacks can be found in streams when migrating to spawn or to the sea to forage. The largest streams are marked on map 15.

### 2.2.3.2. Brooks

*Brooks* often cut through the landscape in the same place from year to year and on their way, create substrates for mats of vegetation (Stonehouse, 1989b). They are shallow and usually dry out in the summer. They can have rich bottom vegetation consisting of aquatic plants, mosses and algae (Fredskild, 1981). Rocks may be covered in diatoms and many filamentous golden brown algae (*Hydrurus*), green algae (*Mirospora*, *Ulothrix* and *Oedogonium*) and filamentous zygnematalean algae (*Zygnema*, *Spirogyra* and *Mougeotia*) are found in some brooks (Kristiansen, pers. comm.).

### 2.2.3.3. Outflow from lakes

*Outflow from lakes* is often clear and has a slower water flow than streams (Røen, 1981). The temperature of the outflow depends on the temperature of the associated lake. Outflows are usually more nutrient rich than the lake itself and support well-developed vegetation, consisting primarily of algae and mosses. In comparison to the other types of fresh water, they also contain a rich midge and entomostracan fauna. Aquatic plants are often sterile in the lake and flower in the more nutrient rich drainage (Fredskild, 1981).

### 2.2.3.4. Springs

*Springs*, which emerge from the ground, are another type of flowing fresh water. Some springs freeze in the winter, while others, where the water temperature is always above freezing, flow year round. The known *hot springs* in West, South and East Greenland are marked on map 15 (Halliday *et al.*, 1974; Kristensen, 1987). These springs should actually be termed *homeothermic springs*, since their temperature is not necessarily higher than the surroundings, but simply constant and above freezing all year round.

Most of Greenland's homeothermic springs are found on Qeqertarsuaq and along the Blossville Coast in East Greenland, where the bedrock is composed of basalt (Klim-Nielsen & Pedersen, 1974). There are thousands of homeothermic springs on Qeqertarsuaq, most of which have a temperature between 0 and 3°C. They are the most thoroughly studied springs in Greenland and have been classified by Kristensen (1987) into three types based on temperature, electrolyte composition and acidity (map 16). Most of the springs that are known from the east coast are located in Liverpool Land and on the Blossville Coast, respectively north and south of Ittoqqortoormiit (map 15). These springs are 38-62°C and thereby have the highest temperatures measured in Greenland. The springs on Greenland's east coast are poorly studied compared to the springs on Qeqertarsuaq. See Halliday and colleagues (1974) and Klim-Nielsen & Pedersen (1974) for studies on the springs in East Greenland.

There are three homeothermic springs with a temperature of 40-42°C on the island of Uunar-toq in South Greenland. They are popular outing destinations and are used for bathing. Like the springs by Engelskmandens Havn and Tarajungitsok on Qeqertarsuaq, they are radioactive (Kristensen, 1987).

Homeothermic springs are unique areas with a special diversity compared to the other fresh-water areas. The warm water affects the local climate and results in the occurrence of specific species in and around the springs. It also results in an accelerated growth rate of plants and animals in the area. Because of varying abiotic conditions among the springs, they are a good example of diversity within a habitat type and the resulting differences in diversity of organisms in the associated ecosystem.

The ground around homeothermic springs thaws early in the spring and thereby extends the plant growing season. The species richness of the vegetation around the springs is therefore often much greater than that of the surrounding terrain, reminiscent of an herb-slope. Snow domes can form around the 6-12°C warm springs in the winter (Kristensen, 1987). This means that a type of greenhouse is created over the spring where growing conditions for plants are particularly good compared to the surrounding terrain. Several plant species have their northernmost occurrence by hot springs in both West and East Greenland. For example, the aquatic plants water alwart (*Subularia aquatica*) and mudwort (*Limosella aquatica*) have their northern boundary at homeothermic springs (Feilberg, 1985). Angelica (*Angelica archangelica*), which is Greenland's tallest herb, and four orchid species are found in association with homeothermic springs, where they benefit from the extended growing season. Two of Greenland's rarest plants are found in connection with homeothermic springs on the east coast. The only observation of the plant species purple avens (*Geum rivale*) has been made at a 54°C homeothermic spring on the Blossesville Coast in East Greenland. *Ophioglossum azorium* is found in the same place and by a more southerly homeothermic spring on the Blossesville Coast. See Kliim-Nielsen & Pedersen (1974) for a list of the flora in the vegetation around the homeothermic springs in Knighton Bay on the east coast and Kristensen (1987) for comments on vegetation associated with homeothermic springs on Qeqertarsuaq.

Algae growth in the warmer springs is characterized by heat-loving blue-green algae. Species of blue-green algae have been found in homeothermic springs in Knighton Bay on the east coast and in springs on Uunartoq in South Greenland, where seven of the ten recorded species are not found anywhere else in Greenland (Kliim-Nielsen & Pedersen, 1974).

Fauna associated with the springs is generally rich in snails, oligochaetes and beetles. The mollusk *Lymnaea vahlii* is found in 50°C water in the springs by Knighton Bay and Qeqertarsuaq. It is rare and is otherwise only known from nutrient rich ponds in South Greenland (Kliim-Nielsen & Pedersen, 1974). Midges, entomostracans, oligochaetes and caddis larvae have also been found here (Røen, 1981). A cold homeothermic spring on Qeqertarsuaq is the only place where the freshwater mite *Lebertia groenlandica* has been found and it should therefore be considered endemic to the area (Lettevall, 1962). Five new species of tardigrades (Tardigrada) have been described from the springs on Qeqertarsuaq, where more than 50 tardigrade species have been recorded (Kristensen, 1987). A new species, *Limnognathia mærski*, placed in its own class, Micrognathozoa, was found in 1994 in a homeothermic spring on Qeqertarsuaq (see section 3.2.3). The springs on Uunartoq in South Greenland and on Qeqertarsuaq by Engelskmandens Havn and Tarajungitsok, are radioactive and have been found to contain animal species (e.g., the coelomate worm *Coelogyneopora biarmata*) that otherwise are known only from the sea at temperatures higher than the ones in Greenland today (Kristensen, 1987).

#### **2.2.4. Standing water**

Lakes, ponds and puddles are termed standing water. All standing fresh water in Greenland freezes in the winter. Ponds are distinguished from lakes in that the bottom freezes in the winter, which by definition, it does not in lakes. Plant and animal life in lakes and ponds is dependent upon factors such as transparency, nutrient content and the water's acidity. The water's clarity and thereby, the amount of light available for algae and aquatic plants, depends on the inflow's distance from the glacier. Lakes that are close to glaciers have poor

transparency and appear gray because of clay particles, while other lakes appear dark blue and clear because the water does not contain dissolved particles (Røen, 1981). The largest lakes are marked on map 15.

In North Greenland some lakes are permanently covered by ice, while the lakes in South Greenland are only covered by ice for half of the year (Røen, 1981). The largest lakes thaw along the shore, but a core of ice remains throughout the summer and water temperatures do not get much higher than just above freezing (Stonehouse, 1989b). Ice floes on large lakes can ruin vegetation on the shoreline (Røen, 1981). In lakes where the shoreline is not destroyed by ice, distinct zones are formed where *Comarum palustre* creates the transition to mire, buckbean (*Menyanthes trifoliata*) follows, and in the deeper parts, a zone with common mare's-tail (*Hippuris vulgaris*) occurs, which is then replaced by burreed (*Sparganium hyperboreum*) (Fredskild, 1981). Aquatic plants are quite often sterile; they only flower where the water is particularly nutrient-rich.

Golden brown algae, diatoms and desmids dominate the plankton in most lakes and ponds. With time, golden-brown algae of the genus *Uroglena* bloom and color the water yellow. Green algae and the nutrient dependent golden-brown algae *Mallomonas heterospina* play an important role in the most nutrient rich waters (e.g., by bird cliffs). Blue-green algae encrust rocks on the bottom and aquatic plants are overgrown by filamentous green algae (Kristiansen, pers. comm.).

#### 2.2.4.1. Nutrient poor lakes

The most *nutrient poor lakes* are found in areas from which the ice has withdrawn recently and the vegetation cover, and hence the addition of organic matter, is still sparse. Characteristic plants include the spiny spore quillwort (*Isoëtes echinospora*), which becomes less common as the amounts of nutrients and ions decrease, burreed (*Sparganium hyperboreum*) and alternate flowered milfoil (*Myriophyllum alterniflorum*). The bottom is covered in moss (*Drepanocladus exannulatus*) and the characteristic algae are of the genera *Oedogonium* and *Microspora*, which are filamentous green algae, and *Lyngbya* (blue-green algae) (Fredskild, 1981).

#### 2.2.4.2. Nutrient rich lakes and ponds

*Nutrient-rich lakes and ponds* are found in areas with runoff from loose soil, raised marine deposits, moraine particles and calcium containing substrates. Characteristic plants such as, slender pondweed (*Potamogeton filiformis*) and Eurasian watermilfoil (*Myriophyllum spicatum*), grow in these areas. In ponds and smaller lakes, especially those in the interior of the large fjord networks, the vegetation is lush and composed of species of pondweed (*Potamogeton* sp.), common mare's-tail (*Hippuris vulgaris*) and *Ranunculus confervoides* in addition to the characteristic plants. A rich algal flora with colonies of bottom dwelling, spherical blue-green algae (*Nostoc pruniforme*), which can reach the size of a tomato, charophytes (the genera *Chara* and *Nitella*), green algae (*Cladophora fracta*) and other blue-green algae (*Coccochloris stagnina*, *Lyngbya* and *Anacystis*) (Fredskild, 1981). Nutrient-rich lakes and ponds that are particularly vegetation-rich, have the richest fauna, composed of several groups of crustaceans (Crustacea), aquatic beetles (Coleoptera) and insect larvae.

#### 2.2.4.3. Saline lakes

*Saline lakes* are found in some areas with low precipitation, for example, at the base of the fjords by the fjord Kangerlussuaq, Uummannaq Fjord and Independence Fjord. In addition to these, high salt concentration lakes are found in both North and East Greenland. Because of the low precipitation, the amount of water that reaches the lakes is less than the amount that disappears via evaporation. The lakes receive meltwater that contains salts released during cliff erosion and the concentration of calcium, sodium and magnesium salts is increased when water evaporates from the surface of the lakes (Røen, 1981). The lakes have a skewed distribution of phosphate and nitrogen and only a few plants can live under these condi-

tions. The only plant that grows in the most saline lakes is slender pondweed (*Potamogeton filiformis*) (Fredskild, 1981). Salt tolerant diatoms and golden-brown algae are found in the plankton (Kristiansen, pers. comm.).

## **2.3. Marine ecosystem diversity**

### **2.3.1. The seas and ocean currents of Greenland**

Greenland is surrounded by several bodies of water (map 17). The Arctic Ocean, Lincoln Sea and Wandel Sea are to the north and the Greenland Sea and Denmark Strait, which opens into the Irminger Basin, are to the east. In the west are the Davis Strait and, north of this, Baffin Bay.

The waters surrounding Greenland are affected by the different currents that meet in the area, as shown on map 2 (Hermann & Olsen, 1981; Buch, 1990; 1991). The cold East Greenland Current transports large amounts of cold Arctic water and pack ice southward from the Arctic Ocean. Between Iceland and Greenland it meets a branch of the Gulf Stream, the Irminger Current, which transports warmer, more saline water. The East Greenland Current and Irminger Current bend by Nunap Isua and follow Greenland's west coast northward. The mixing of the two currents causes the coastal current along the southernmost part of the west coast to lose some of its characteristic polar current traits. Instead it is a temperate, almost ice free current in this region, the West Greenland Current. A branch of the West Greenland Current veers west north of Nuuk, where it mixes with the colder Canadian Polar Current and follows it southward. A section of the West Greenland Current continues northward causing the temperature of the water in Baffin Bay to be significantly higher in the eastern part than in the western part, where the cold Canadian Polar Current dominates.

The transportation of water with different salinities and temperatures by ocean currents, and the dispersion of ice and marine organisms are of fundamental importance to the distribution and composition of marine ecosystems. The relationship between the cold East Greenland Current and the warmer, more saline Irminger Current, varies from year to year and affects the distribution of marine species. It also affects which species of, for example, fish and marine mammals, enter the waters surrounding Greenland. Planktonic organisms are transported and spread by ocean currents, as are the eggs and larvae of invertebrates and fish. The system of currents influences primary production and determines which areas experience an upwelling of nutrient-rich water, which is the basis for a high level of primary production.

The system of currents is also important in the transportation and distribution of sea ice. The East Greenland Current leads the so-called East Greenland Drift Ice (multi-year drift ice of polar origin) from the Arctic Ocean southward, while the Canadian Polar Current leads ice masses, termed the West Ice, from Baffin Bay towards the south. The distribution of sea ice varies from year to year depending upon currents and so-called "open water areas" are found off the coast of Southwest Greenland and in other areas (polynyas) with varying degrees of open water throughout the year (map 18).

### **2.3.2. Primary production**

Unicellular algae, also termed phytoplankton, are the basis of life in the sea, while attached algae only have a minor role in this respect (Hansen & Smidt, 1981). Algae are autotrophic organisms that convert carbon dioxide and water to energy rich organic combinations with the help of sunlight. The process, known as photosynthesis, is essential for the growth and thus, production (primary production) of algae (Sakshaug *et al.*, 1992).

Primary production is regulated by both physical/chemical and biological factors including light, temperature, level of mineral nutrient content, grazing and algae deposition. The most

important factors in marine primary production appear to be solar irradiation and the occurrence of mineral nutrients. Primary production in Arctic regions is influenced by extreme light conditions, varying from darkness in the winter to midnight sun in the summer. This, along with other physical factors, limits the growth period to five to six months of the year (Smith & Sakshaug, 1990; Stonehouse, 1989c). Primary production only occurs in the top, light exposed section of the water column and decreases exponentially with increasing depth.

When light conditions become favorable in the spring, an explosive bloom of phytoplankton occurs. This bloom is dependent upon the formation of a stable, nutrient containing water layer in the irradiated zone. Winter storms mix the water column and bring nutrients from the bottom into the upper layers. When the surface water heats up, making it less dense than the water below, a pycnocline is formed. The pycnocline prevents algae from sinking and as long as nutrients are present, the upper irradiated layer experiences a tremendous algal bloom.

In the waters surrounding Greenland, the spring bloom starts in the open water region off the coast of South Greenland (map 18) and moves northward. North of the open water region, production begins under the ice. However, the start of the actual spring bloom is dependent upon the retreat of the ice. Phytoplankton species composition changes over the course of the season. During the spring bloom, the phytoplankton is dominated by the bacillariophytes (diatoms) *Nitzschia*, *Thalassiosira*, *Navicula*, *Fragilaria* and *Coscinodiscus* (Heimdal, 1989; Nielsen & Hansen, 1995). After the spring bloom, the phytoplankton community is composed of smaller species of phytoplankton, such as those of the genera *Phaeocystis*, *Chaetocerus* and *Ceratium* and dino- and nanoflagellates (Heimdal, 1989).

The waters surrounding Greenland can be divided into several regions that are very different with respect to primary production. These differences are due to hydrographical variation, the presence of ice and meltwater, water depth and latitude. As a general rule, the bulk of primary production occurs close to the coast and in fjords, where both a spring and late summer bloom occurs. Furthermore, the Polar Front, between the Irminger Current and the East Greenland Current, creates an upwelling of nutrient rich water to the upper water layers throughout the summer. Because of this, the front areas have a high level of primary production over a long period, creating the basis for a rich occurrence of zooplankton and fish (Hansen & Smidt, 1981). Production in Davis Strait and Baffin Bay is lower than in the regions near the coast. Within the last few years, it has been found that a significant amount of primary production occurs in connection with the melting of sea ice (Sakshaug *et al.*, 1992). This will be discussed further in section 2.3.9.1.

### **2.3.3. Zooplankton**

Zooplankton are the link between phytoplankton and higher organisms in the pelagic ecosystem and are called secondary producers. Primary production, which comprises the staple diet for zooplankton, is short-lived. Zooplankton in the Arctic therefore have a longer life cycle than in temperate and tropical waters and have a temporally well defined spawning period (Hansen & Smidt, 1981).

The term zooplankton includes both uni- and multicellular organisms that can be roughly divided into heterotrophic micro- and macroorganisms. Microzooplankton include, among other things, bacteria and protozoa. Bacteria obtain energy by decomposing organic matter transported across the cell membrane. Protozoa are colorless flagellates and ciliates that live off of dead particles, phytoplankton, bacteria and smaller protozoans (Sakshaug *et al.*, 1992). Bacteria are grazed by protozoans, which in turn are consumed by larger microorganisms such as flagellates and ciliates. Heterotrophic microorganisms are important for the remineralization of mineral nutrients, that is, the recycling of nutrients that have been used by one or more plankton generations.

In Greenland, holoplankton, organisms that are pelagic throughout their life, dominate the zooplankton in the sea and by the coast. Holoplankton include several different organisms, the most important being crustaceans, pteropods, jellyfish, ctenophores and arrow worms (Hansen & Smidt, 1981). Crustaceans have the most important role since they form the staple diet for several other species. Copepods (Copepoda) are the most dominant crustaceans. They are important grazers of phytoplankton and greatly influence carbon metabolism. They comprise about 86% of the zooplankton biomass, with 84% of these belonging to species of the genus *Calanus*. *Calanus* is thought to be one of the most important animal groups in northern marine regions (Hansen & Smidt, 1981). The species *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus* are key species in the food chain. *C. finmarchicus* is common in the waters surrounding Greenland, whereas the other two are also found in Arctic waters. In the spring and summer these copepods live in the top water layers to a depth of about 100 m. Here they are closely bound to phytoplankton and feed exclusively on algae. Towards the late fall and during the winter, they seek deeper water where they reside without consuming anything. During this period, they metabolize the energy reserves (triglycerides and fatty acids) that were stored up at the end of the season. The copepods *Metridia longa* and species of the genera *Paracalanus*, *Pseudocalanus*, *Oncaea*, *Oithona* and *Microsetella* are also present in the pelagic ecosystem, but are not nearly as dominant as species of the genus *Calanus*.

Other crustaceans in the pelagic ecosystem that should be mentioned are krill (Euphausiacea). Krill are thought to be less important for decomposition than copepods, but are an important link between phytoplankton and fish, marine birds and marine mammals.

Zooplankton is also composed of meroplankton, species that are pelagic for part of their life cycle. Meroplankton is found mainly in the high productivity areas along the coasts, in fjords and above banks. The larvae of crustaceans, particularly those of barnacles, crabs and shrimp, dominate the meroplankton, but the larvae of fish, echinoderms, bivalves, snails and polychaetes are also present (Hansen & Smidt, 1981).

#### **2.3.4. Benthos**

The wintering population of zooplankton is small and does not have time to increase, therefore the bloom of algae cannot be fully utilized. Algae surpluses sink toward the bottom, as do faeces and other animal remains. Since the decomposition of organic matter is slow, the deposition of organic materials provides the foundation for a rich benthic fauna throughout the year.

Benthic invertebrates are filter feeders, detritus feeders or predators of other benthic animals. A differentiation is made among *infauna*, which live buried in the bottom substrate, *epifauna*, which live on the bottom and *interstitial fauna*, which live between individual substrate particles. The most dominant groups of infauna are polychaetes and bivalves. Epifauna include sedentary organisms, such as tunicates, sea anemones, bryozoans and barnacles, and free-living organisms such as, shrimp, crabs, snails and echinoderms. The interstitial fauna is made up of meiofauna (animals < 1 mm), such as kinorhynchs (Kinorhyncha) and loriciferans (Loricifera).

#### **2.3.5. Marine birds, fish and mammals**

As already mentioned, crustaceans, especially species of the genus *Calanus* and krill (Euphausiacea), are important in the marine ecosystem. Fish, fish larvae, birds and marine mammals all feed on crustaceans. Among the pelagic fishes, polar cod (*Boreogadus saida*) and capelin (*Mallotus villosus*) play the most important role in the ecosystem as prey for several predators. Polar cod are a key species in High Arctic ecosystems, while capelins are of greater importance in the more southerly regions (Søder, 1994).

Most of Greenland's birds are bound to the sea and live primarily on a diet of crustaceans and small fish like the capelin. The proportion of fish and crustaceans in the diet varies among species. For example, murrelets (*Uria aalge*) eat both fish and crustaceans, while little auks (*Alle alle*) eat only crustaceans, and puffins (*Fratercula arctica*) prefer fish. Glaucous gulls (*Larus hyperboreus*) and great black-backed gulls (*L. marinus*) are omnivorous and will eat the young and eggs of other marine birds (Salomonsen, 1990). Both common eiders (*Somateria mollissima*) and king eiders (*S. spectabilis*) forage on benthic fauna. King eiders primarily search for prey on soft substrates, but will also forage on hard substrates. The majority of their diet is composed of bivalves, particularly *Mya truncata*, *Serripes groenlandicus* and *Cardium cilatum* (Frimer, 1995a; 1995b).

Sand lances (*Ammodytes* sp.) and capelins are important food items for salmon, cod and other fish. Salmon, however, supplement their diet with krill, shrimp, crabs and other benthic organisms. While skates (*Raja* sp.) and Greenland halibut (*Reinhardtius hippoglossoides*) retrieve a large amount of their prey items from the bottom, namely benthic bivalves and pink shrimp (*Pandalus borealis*), catfish (*Anarhichas* sp.) and sanddabs (*Hippoglossoides platessoides*) are actual benthos feeders (Hansen *et al.*, 1981).

Blue whales (*Balaenoptera musculus*) and bowhead whales (*Balaena mysticetus*) feed exclusively on crustaceans and other planktonic organisms, while the other great whales, to greater or lesser degrees, supplement their diet with fish. Minke whales (*Balaenoptera acutorostrata*) feed on crustaceans, cephalopods, capelins, herring (*Clupea harengus*), cod and other fish. Its varied diet makes the minke whale less dependent on the short plankton season than the whales that primarily feed on crustaceans (Vibe, 1990a).

Among the toothed whales, killer whales, or orcas, (*Orcinus orca*) and sperm whales (*Physeter catodon*) are able to take the largest prey. Killer whales feed mostly on fish and cephalopods, but sometimes take birds and other marine mammals (Vibe, 1990a). When in a pack, killer whales can attack large baleen whales, narwhals (*Monodon monoceros*), beluga whales (*Delphinapterus leucas*) and walrus (*Odobenus rosmarus*). Sperm whales primarily feed on cephalopods but will also hunt skates and sharks. Beluga whales feed on fish, such as polar cod, Greenland cod (*Gadus ogaq*), ocean perch (*Sebastes marinus*), catfish and Greenland halibut (Vibe, 1990a). Narwhals feed on polar cod but will also predate upon the bottom's Greenland halibut and eelpouts (*Lycodes* sp.), cephalopods and other benthic animals (Vibe, 1990a).

Seals feed on crustaceans and fish. Harbor seals (*Phoca vitulina*) feed exclusively on fish, such as herring, sanddabs and salmon, while bearded seals (*Erignathus barbatus*) have a more varied diet. In addition to fish and crustaceans, the bearded seal also eats benthic fauna including snails, sea cucumbers (Holothuroidea) and sea squirts (Ascidiacea).

Walrus have a narrow food niche and mainly eat benthic bivalves, which they take from banks with depths of less than 80 m (Vibe, 1990a). They will also prey on seals when possible or when ice conditions make it impossible for them to forage on the banks (Born *et al.*, 1995).

Polar bears (*Ursus maritimus*) primarily feed on harbor and bearded seals, but will also hunt harp seals (*Pagophilus groenlandicus*) on pack ice, hooded seals (*Cystophora cristata*) on occasion, and walrus only rarely. They also take marine birds and can catch geese on land (Vibe, 1990a).

### **2.3.6. The coast**

Greenland's coast has a countless number of large and small islands and fjords and because of the several thousand fjords and bays, has a length of about 40,000 km (Taagholdt, 1981). It is principally a cliff coast with numerous rock outcrops, islands, deep fjords and large fjord networks.

The coast and some of the fjords are characterized by relatively high primary production (Petersen, 1964; Steeman Nielsen, 1975; Smidt, 1979; Andersen, 1981; Nielsen & Hansen, 1995; Burmeister *et al.*, 1995). In addition to the spring bloom of phytoplankton, a late summer bloom also occurs. The recycling or transport of nutrients up to the top water layers, which happens due to weather conditions, causes this late summer bloom. Because of high primary production, life along and near the coast is rich in comparison to the rest of the marine environments.

The coasts and regions near the coast support several important habitats. Coastal regions encompass a number of areas important for Greenland's birds, most of which are bound to the coast. For example, *bird colonies*, where thousands of birds gather to breed, and *moulted areas*, where birds gather to moult their feathers, are found along the coast. There are *haul-outs* for harbor seals and walruses on the coast and marine environments near the coast function as *spawning* and *maturation grounds* for fish, including capelins and lumpfish (*Cyclopterus lumpus*). Arctic char (*Salvelinus alpinus*) stay close to the coast during their migration out to sea.

#### 2.3.6.1. Bird colonies

A characteristic trait of marine birds is that they do not occupy territories. Instead they breed in colonies often comprised of thousands of birds in a relatively limited area. They gather on steep cliffs oriented towards the sea, termed *bird cliffs*, or on small islands and rock outcrops, termed *bird islands*. In West Greenland two-thirds of marine bird colonies are on bird cliffs, the rest are on bird islands (Boertmann *et al.*, 1996).

There are 1,032 registered colonies in West Greenland with around one million colony nesting marine birds. This corresponds to about 84% of all bird colonies in Greenland (Boertmann *et al.*, 1996). Additionally, there are about 40 million little auks in enormous colonies in Avanersuaq. These colonies most likely support 80% of the world's breeding little auks and are of great international importance (Nettleship & Evans, 1985). The most important areas in West Greenland for colony nesting birds are shown on map 19.

Since bird cliffs are steep, inaccessible areas, they are normally protected from disturbance from natural predators. Therefore, the birds are especially sensitive to disturbance from human activities in the areas around bird cliffs. Their defense strategy is to escape from the threat and they react strongly, even if only slightly agitated. Disturbances during breeding periods can result in parental desertion of eggs and young (Chardine & Mendenhall, 1998). Birds that do not build nests, but lay their eggs directly on the cliffs or, as with the thick-billed murre (*Uria lomvia*), incubate their eggs on their feet, are especially at risk of losing their eggs or young if they flee.

It is presently illegal to shoot or generate noise within 5 km of a bird cliff if it is occupied by murre, thick-billed murre, little auks, kittiwakes (*Rissa tridactyla*), northern fulmar (*Fulmarus glacialis*) or great cormorants (*Phalacrocorax carbo*). If the bird cliff is a small, more or less flat island inhabited by common eiders, king eiders, black guillemots (*Cephus grylle*), terns or gulls other than kittiwakes, the same rules apply within a distance of 200 m (Anon., 1989).

#### 2.3.6.2. Moulting areas for king eiders and common eiders

Several thousand birds gather in the early autumn to shed their flight feathers. Birds are unable to fly for a period of about 3-4 weeks when they are moulting, making them extra vulnerable to predators and other disturbances (Frimer, 1994a; 1995). Therefore, birds gather in *moulted areas* in fjords and bays, which provide protection from predators and disturbances and good foraging possibilities (Frimer, 1993).

Qeqertarsuaq Tunua has long been recognized as an important moulting area for king eiders (Salomonsen, 1968). The birds apparently gather in the relatively undisturbed western and

northern parts of Qeqertarsuaq. However, the southern part of the island gets disturbed, making it less favorable for moulting (map 20). In fact, in the past few years, only a few hundred moulting birds have been recorded in the Ramsar site Aqjarua - Sullorsuaq in the southeastern part of Qeqertarsuaq. At one point, the Ramsar site was the August moulting area for 30,000 king eiders (Anon., 1996a). Hunting and sea scallop (*Placopecten magellanicus*) fishing in the area may have caused the drop in the number of moulting birds (Frimer, 1993). The degree to which the population has declined versus that to which the birds have been displaced to other areas is unclear (Frimer, 1993).

The fjord Kangersooq on the northwestern part of Qeqertarsuaq with the Ramsar site, Qinnuata Marraa - Kuussuaq at the inner part of the fjord, as well as the fjord network on southern Upernavik, especially Umiarfik fjord, are currently the most important areas for moulting king eiders in West Greenland (Anon., 1996a; Merkel, pers. comm.).

Common eiders also moult on Qeqertarsuaq (map 21). The highest concentration of moulting birds is found in the outer bays and fjords along the western part of the island and the archipelago by Kitsissut (Frimer, 1993). In addition, the fjord networks on southern Upernavik are currently important moulting areas for common eiders (Merkel, pers. comm.).

Some king eider moulting areas are located on Ramsar sites. These are areas that Greenland has declared as internationally important for waterfowl, and is therefore obligated to protect (all Ramsar sites are indicated on map 14).

#### 2.3.6.3. Haul-outs for walruses

Walruses will occasionally haul-out onto land on islands or capes, where they gather on so-called *haul-outs* ("uglit"). Historically walruses have had several permanent haul-outs in West Greenland, all in the area where the West Ice abuts land (Vibe, 1990a). Born and colleagues (1995) mention 10 haul-outs in central West Greenland that were used by walruses before the 1930s. The haul-outs were mostly located on the coast between Attu, south of Aasiaat, and Kangaamiut. The haul-outs are no longer in use due to increased hunting pressure. It is unclear whether the walruses have been exterminated from the areas or simply have learned to stay away and use the West Ice instead (Born *et al.*, 1995). At one point there were also a couple of haul-outs in both Upernavik and Qanaaq Counties.

The only haul-outs known today are in East Greenland (map 22). They are Sandøen (74° 15' N) and Lille Snenæs (76° 52' N), where approximately 50 males haul onto land in each place in August and September (Born *et al.*, 1995; 1997). There used to be other haul-outs in East Greenland, but these were abandoned at the beginning of the 20<sup>th</sup> century because of hunting (Born *et al.*, 1995).

The only two known haul-outs are in the National Park (map 14) and are therefore protected by the laws governing the area (Anon., 1989).

#### 2.3.6.4. Haul-outs for harbor seals

Harbor seals gather in groups on land during the summer to give birth, nurse their young and shed their fur. On these haul-outs the seals are easy to approach within shooting distance, making them more vulnerable to hunters than Greenland's other seal species (Teilmann & Dietz, 1994).

The actual status of the harbor seal population is unknown. It has probably been declining since the beginning of the 20<sup>th</sup> century and has disappeared from at least nine out of 23 known breeding sites (Teilmann & Dietz, 1993) and decreased in number at others. For example, 500-600 harbor seals were observed by the fjord Kangerlussuaq in the 1960s and today there are only 20 or so left (Teilmann & Dietz, 1994).

It has been suggested that climate changes have contributed to the decrease in the harbor seal population (Kapel & Peteresen, 1982). However, Teilmann and Dietz (1993) emphasize that sources indicate the decline has been occurring for close to a century, independent of climatic variation. They suggest that increased hunting pressure and boat traffic and the catching of seals in char and salmon nets may be factors contributing to the decline.

Adult harbor seals are protected from the 1<sup>st</sup> of May to the 1<sup>st</sup> of October. In addition, there are local resolutions that protect certain haul-out areas in Paamiut and Qaqortoq Counties from hunting and disturbance.

### 2.3.7. *The littoral zone*

The area between high and low tide lines is termed the *littoral zone*. The water level varies greatly between the high and low tide since Greenland's coasts are oriented more or less toward the oceans. The largest differences in water levels are found in small bays and fjords (Bertelsen *et al.*, 1989).

Organisms that live in the littoral zone are exposed to various conditions and environmental changes both daily and throughout the year. They have to be able to tolerate varying amounts of desiccation over a 24-hour period. They must also be able to tolerate being frozen for part of the year and to withstand the mechanical effects of waves and ice for the remainder of the year. The littoral zone is also affected by freshwater influxes from melting sea ice and meltwater streams on land. Solar radiation is a determining factor for the melting of ice and for the degree of desiccation that sedentary organisms are subjected to during low tide. The factors mentioned above vary from region to region and the organismal makeup may therefore be different from coast to coast, even over small distances (Marin ID, 1979).

On the cliff coasts the littoral zone, from the high tide line toward the low tide line, is characterized by a green band of green algae, a white band of barnacles and a brown band of brown algae (Petersen & Smidt, 1981). The organisms that create the characteristic, colored bands are the foundation of communities in the littoral zone. Green algae are grazed by periwinkles (Littorinidae). The influx of fresh water reduces the number of periwinkles, causing green algae to become more common. Barnacles, all of which belong to the species *Balanus balanoides*, are never found below the low tide line and have their northernmost boarder by Upernavik in the west and Tasiilaq in the east. They filter plankton from the water and are themselves eaten by periwinkles and birds, including ravens, dunlins, and gulls. Dogwhelks (*Nucella lapillus*) are only found in a few small fjords by Qaqortoq and Paamiut in the littoral zone, from the low tide line to the middle of the littoral zone, where they primarily feed on barnacles (Petersen & Smidt, 1981). Flat periwinkles (*Littorina obtusata*) are associated with bladder wrack (*Fucus vesiculosus*) and the snail *Margarita helicina* is found at and below the low tide line.

Attached marine algae create a forest of seaweed from the lower part of the littoral zone to about a 30-50 m depth. It is primarily composed of sea colander (*Agarum cribrosum*) and dry kelp (*Laminaria longicuris*) with a growth of smaller red, brown and green algae and calcified red algae in the "understory" (Christensen, 1981). Seaweed forests function as habitat for a number of invertebrates such as, snails, hermit crabs, sea urchins and crabs. Butterfish (*Pholis gunellus*) live in seaweed forests permanently and kelp snailfish (*Liparis tunicata*) are common, while capelins and lumpfish only seek out these areas to spawn. Capelins gather in enormous spawning schools in the same places year after year, some of which are in seaweed forests. During the same time period, lumpfish cluster in seaweed forest areas to spawn in the shallow water between the rocks and the seaweed. Hence, seaweed forests are nurseries for several fish larvae and young lumpfish. Butterfish and capelins in seaweed forests are an important food resource for marine birds, such as thick-billed murre and gulls and for sculpins and cod (Muus, 1990).

### 2.3.8. Fjords

The length of Greenland's coastline, and the extent of regions near the coast, is significantly increased by the many thousand fjords and fjord networks that cut into the landscape.

Fjord regions occupy an area of about 170,000 km<sup>2</sup> (map 23). Kejser Franz Josehps Fjord and Kangertittivaq are on the east coast. They are not only the largest fjord networks in Greenland, but are among the largest in the world. West Greenland's largest fjord regions are the fjords Kangerlussuaq, Nassuttooq and Nuup Kangerlua.

Fjords are often old glacial valleys. Size, topography and the effects of wind, tides, glaciers and freshwater influxes from the surrounding landscape vary from fjord to fjord. Organismal makeup and production can therefore vary greatly among fjords, making it difficult to generalize living conditions. However, fjords can be divided into two types based on bottom topography.

In *open fjords*, where coastal water can flow in freely, warm bottom water flows in along the bottom and wells up in the inner parts of the fjord, which then become enriched with nutrients. The same stratification of water occurs in this type of fjord as offshore, and water in the bottom layers will always have temperatures above freezing. Fjords with warm bottom water create favorable environments for pink shrimp, which often dominate the benthic fauna in the deep estuaries, while the fish fauna is dominated by boreal species (Petersen & Smidt, 1981; Muus, 1990). Examples of open fjords include Kuannersoq south of Paamiut and Bredefjord north of Qaqortoq (Wesengerg-Lund, 1950).

Most of the fjords in West Greenland are *constricted fjords* and have one or more constrictions that prevent water masses inside and outside the fjord from mixing freely. Low water depths at the mouth of the fjords prevent the warmer, deeper water from flowing in and a layer of cold water lies at the bottom year round. This creates High Arctic conditions near the bottom. In the winter, the entire water column may reach temperatures below freezing (Hermann & Olsen, 1981). Constriction fjords are generally nutrient-poor because of the lack of mixing. They often have few fish and marine mammals and are dominated by Arctic species (Vibe 1990a; Muus, 1990). The fjord Nassuttooq on the border between Sisimiut and Kangaatsiaq County is an example of a constriction fjord (Wesenberg-Lund, 1950).

Included in the two above-mentioned fjord types are *glacier fjords*, which are fjords where glaciers reach into the fjord and icebergs break off. This influences the hydrography of the fjords by mixing the water column when a glacier calves. Tall calving waves ("Tagsaq") that fling sea water, plants and animals onto the coast are created. Icebergs and glaciers themselves also influence hydrography when they thaw by creating a layer of brackish water that rises to the surface. This brings mineral nutrients to the surface and increases production in the fjord. Contrarily, production in a glacier fjord may be limited if the glacier adds large amounts of sediment to the water, decreasing the water's clarity and thereby, reducing algae production.

Open fjords that are near glaciers are generally deep. In West Greenland they are rich in fish and in Northwest and East Greenland they are rich in seals and whales. Frequent winds from the Greenland Ice Cap push surface waters outward. Closest to the glacier, this water is substituted by warmer, nutrient rich bottom water. There are always good fishing possibilities in the summer at the base of such fjords and many of Greenland's settlements are therefore near active glaciers with frequent winds from the Ice Cap (Vibe, 1990a).

The fjord Kangia is probably the best known glacier fjord in Greenland. The glacier here, Sermeq Kujalleq, is the most productive in the northern hemisphere. It moves at a speed of approximately 1 m per hour and produces about 30 km<sup>3</sup> of icebergs per year, accounting for 10% of the total Greenland Ice Cap iceberg production. The fjord Kangia is a remarkably

beautiful natural area. It is rich in opportunities to study the creation of icebergs and human settlement patterns around the fjord can be followed in relation to the glacier's distribution over time. The fjord has been recommended as a World Heritage Site since there are no other areas like it on earth (Nordisk Ministerråd, 1996).

#### 2.3.8.1. Ikka Fjord

Ikka Fjord is a relatively shallow side fjord to the deep Ilorput Fjord in South Greenland near Ivittut (map 24). It is a cold and nutrient-poor constricted fjord. Only a few fish occur here making seals and marine birds uncommon. Buchardt and colleagues (1996) studied the fjord. There are thousands of column-like structures rising up from the fjord bottom in the innermost part of the fjord. They range in size from a few centimeters to over 20 m high. The columns are made up of a rare calcium mineral, ikaite, named after the fjord. Ikaite has only been described from six localities in the world, all of which are under water and at temperatures close to the freezing point of water. The columns are formed when fresh water under pressure streams up from the fjord bottom. When this spring water makes contact with seawater, the mineral ikaite is precipitated out. Spring water is less dense than seawater and flows upward, thus creating ikaite columns.

Environmental conditions for flora and fauna on the columns and in the inner part of Ikka Fjord are not very different from those of other low productivity fjord areas with constant temperature and salinity. Column surfaces are overgrown with crusts of calcified red algae and other algae, which are grazed on by echinoids. Mussels, barnacles, hydroids and sponges that can tolerate low salinities are found on the columns' upper parts. Starfish, sea anemones, sun stars and echinoids are the most noticeable animals on the other parts of the columns. A more detailed description of the fauna associated with the columns is given by Thorbjørn (1996).

Biological conditions in Ikka Fjord are not necessarily unique in comparison to those in neighboring fjords. However, the ikaite columns' vertical surfaces with pores and crevices that experience a mixing of salt and fresh water are a unique environment. Cryptomonads have been found that live both in and on the columns, thus tolerating the lower salinity inside the columns. With careful inspection, more organisms that are adapted to the unique environment inside the columns will probably be found (Buchardt *et al.*, 1996). As mentioned, the creation of ikaite has only been observed six places in the world and it would therefore be justified to recommend that Ikka Fjord be declared a World Heritage Site. In 2000 Ikka Fjord was protected under Federal Law no. 11, 12 November 1980, see section 4.2.2.

#### 2.3.9. Sea ice

Sea ice plays an important role in the ecosystems of the waters surrounding Greenland. It isolates marine areas from the atmosphere and prevents light from penetrating the water for a large part of the year. This influences primary production and thereby life in general in areas with sea ice. The ice also affects the distribution of animals and their migration patterns, as with marine mammals that must surface to breathe and wintering marine birds that must forage in open water. The ice also functions as a platform for seals, walruses, polar bears and marine birds.

Sea ice that is formed during the winter is termed *annual ice*, while sea ice several meters thick that survives the summer thaw is termed *multi-year ice*. Sea ice is very dynamic and both distribution and shape vary from year to year and locally, depending on wind and current conditions in the individual areas. The average distribution of sea ice in the winter is shown on map 18. *Fast ice* is formed in association with the coast. *Fjord ice* forms inside the fjords and *land ice* forms by the outer coasts. *Pack ice* includes all forms of sea ice that are not fast ice. It can be described as a form of ice that has a varying degree of open water between parts. Pack ice is led from the Arctic Ocean down along the east coast of Greenland and

together with the local sea ice is the basis of the East Greenland Drift Ice. This is then led by ocean currents around Nunap Isua and up along the west coast, from where it slowly makes its way up to Maniitsoq. The West Ice is pack ice formed in Baffin Bay and Davis Strait (Buch, 1990).

In certain places sea ice is broken up when the tides go in and out and channels, or leads, are formed that temporarily have open water. Tidal furrows are found between the coast's ice base and fast ice, while coastal furrows are formed between pack ice and the coast or fast ice (map 18). Leads are also found around grounded icebergs. Leads, which open and close with the changing water level, are important for wintering marine mammals. For example, they allow ringed seals (*Phoca hispida*) and bearded seals, to change foraging areas if fast ice in the fjords gets so thick that it is difficult for them to keep breathing holes open (Vibe, 1990a).

In southwestern Greenland, between marine areas with East Greenland Drift Ice and West Ice, is a region with open water year round (map 18). This open water region is very important for marine birds including eiders, king eiders and thick-billed murres, that gather here in the thousands during the winter (Salomonsen, 1990). There are also open water areas of varying size and shape in the pack ice. These *polynyas* are formed in almost the same places and at the same time every year. Polynyas are dynamic, fluctuating areas with open water and a distribution dependent upon factors such as wind, ocean currents, tidal currents and the upwelling of warmer water masses (Søder, 1994). In the waters surrounding Greenland, the largest polynyas occur in the North Water in the northern part of Baffin Bay and in the Northeast Water by Nordøstrundingen (map 18). Polynyas are important wintering areas for Arctic marine mammals: bearded seals; ringed seals; walruses and to some degree, polar bears, narwhals and beluga whales (Vibe, 1990a). In addition, High Arctic marine bird colonies are often found in association with polynyas or by coastal furrows and leads where it is possible to forage in the open water (Brown & Nettleship, 1981).

#### 2.3.9.1. *Communities associated with the ice*

With its varying distribution and consistency, ice is the foundation for a number of communities that include algae, crustaceans, fish and marine mammals. Most of the ice is in the form of pack ice, which is moved about by currents and winds and thereby, influences the distribution of species associated with it.

Unicellular algae, ice algae, are found in association with the ice where they complete part of or their entire life cycle. A distinction is made between different communities depending upon where on the ice the algae live. They grow on the underside of the ice in *interstitial communities* in cavities, cracks and crevices and in *under-ice communities*, where they hang down from the underside of the ice (Sakshaug *et al.*, 1992). Ice algae, which like the remaining phytoplankton are dominated by diatoms, are adapted to the low solar irradiation conditions under the ice and can grow with 0.1% of the light hitting the surface of the ice (Andersen, 1989). If the ice is annual, the algae have to be recruited anew every year.

Ice algae are grazed by an ice fauna of crustaceans including amphipods (Amphipoda), copepods (Copepoda) and krill (Euphausiacea) (Grainger *et al.*, 1985). The ice fauna is composed of a *true ice fauna* found in cracks, crevices and channels on the underside of the ice and a sub-icefauna, which is not physically bound to the ice, but is part of the food chain (Sakshaug *et al.*, 1992). On multi-year pack ice the fauna is composed of crustaceans, with ice amphipods dominating the group. Crustaceans on the ice are grazers, omnivores and carnivores. On the coastal fast ice (at 50-100 m depths) amphipods take advantage of the early bloom of algae for spawning and growth (Søder, 1994). Meroplankton, such as bivalve larvae, barnacles and polychaetes are found temporarily on the ice. Polar cod, which function, for marine mammals, as the most important food source associated with the ice, are opportunist feeders and feed on the ice fauna (Sakshaug *et al.*, 1992).

Production associated with the ice is greatest at the ice edges, between the open sea and sea ice, where the so-called ice edge effect occurs with the melting of ice in the spring. The ice melt combined with the heating of surface waters creates a stable, nutrient rich water mass in the upper layer. It provides favorable growing conditions for phytoplankton and the spring bloom can occur in a 20-50 km wide band along the ice edge (Sakshaug *et al.*, 1992). Fish, such as the capelin, which follows the retreat of the ice edge, exploit the vigorous growth of zooplankton that follows the bloom. Larger fish, whales and seals follow capelins. The ice edge also attracts marine birds such as ivory gulls (*Pagophila eburnea*), little auks, kittiwakes and murrelets, which in turn act as food sources for snowy owls (*Nyctea scandiaca*) and ravens (*Corvus corax*) (Kampp, 1981). The ice edge should be considered a very important area since many species seek it out due to its relatively high productivity.

### 3. *Species diversity in Greenland*

The majority of Greenland was covered by ice during the last ice age; only a few areas in West, East and North Greenland were ice-free. The ice-free areas probably functioned as refuges where a few cold tolerant species could survive the Ice Age. Other than this, it can be assumed that all life was exterminated and that current species invaded Greenland after the Ice Age ended about 10,000 years ago.

The immigration of species to Greenland is hampered by its isolation as an island. Species that arrived from the east either traversed the distance on their own or were transported by other species or wind and ocean currents. Species that arrived from the west crossed north-eastern Canada, where the High Arctic climate probably placed strong selection pressure on them and resulted in species well adapted to the Arctic immigrating from this direction. A third immigration route, used by North American Low Arctic species, is via Labrador to southern Greenland.

As with other landmasses in the Northern Hemisphere, species diversity decreases from the south to the north in Greenland. Adaptations to cold and drought are the primary factors determining the distribution of terrestrial species. In addition to the gradient in species diversity from north to south, for some terrestrial groups the number of species decreases from inland to coastal areas. The distribution of marine species is primarily dependent up ocean currents, which, among other things, are determinative for water temperature and salinity and for the distribution of sea ice.

A limited number of species are endemic to Greenland, i.e. only occur in Greenland. Endemic species of algae, vascular plants and a single water mite (*Hydracarina*) have been recorded in Greenland. A few bird subspecies breed only in Greenland, but they winter elsewhere. The small number of endemic species may be attributable to the fact that almost all species present today had to immigrate to Greenland after the last ice age. The time period over which new species could have evolved in Greenland is probably too small for new species to appear.

In the nationwide study of Greenland about 9,400 species are documented (table 3). This number only includes the species that are represented in the study and the actual number of species occurring in Greenland is higher. Since the amount of information available for individual taxonomic groups varies, not all groups are treated with equal thoroughness. An attempt has been made to collect all the information currently available about individual groups. For some taxonomic groups the number of species was known beforehand (*e.g.*, plants and birds), while for other groups (*e.g.*, arthropods and marine invertebrates), it was necessary to take a species survey in conjunction with this report. There are therefore databases with all species names within a group for some groups, while for other groups, only the number of species in various subgroups is provided (table 3). The distribution of single species has been mapped (see section 6).

**Table 3.** Overview of the number of species represented in the nationwide study of Greenland by taxonomic group.

Taxonomic group	Number of species	Source/Comments
Fungi	app. 1600	Knudsen, 1999. See table 4 for the distribution of 717 species in the subphylum Hymenomycota, which among others includes the edible fungi
Lichens	app. 950	Hansen, 1993b. A database of 930 species in about 170 genera can be found at the Greenland Institute of Natural Resources (Grønlands Naturinstitut).
Phytoplankton, freshwater	app. 1900	Compiled by Jørgen Kristiansen, 1996. See table 15.
Phytoplankton, marine	>400*	Braarud, 1935; Grøntved & Seidenfaden, 1938; Thomsen 1982 and others. *The number of species has not been determined for each group.
Attached marine algae	215	Pedersen, 1976; Pedersen, 1997 unpubl. Rev. See table 16. A database with species names can be found at the Greenland Institute of Natural Resources (Grønlands Naturinstitut).
Bryophyta (mosses)	app. 612	Mogensen, 1987. See table 6 for the distribution of species among the four groups of mosses.
Tracheophyta (vascular plants)	515	Bay, 1997. See tables 7, 8, 9, 10 and 11. A database with species names can be found at the Greenland Institute of Natural Resources (Grønlands Naturinstitut).
Arthropoda (arthropods)	931*	Compiled by Jens Böcher, 1997. *The number includes terrestrial and freshwater arthropods, but not marine arthropods, which are represented under marine invertebrates. See tables 12 and 13.
Marine invertebrates	>2000	Compiled by Lone Thorbjørn, 1997. The number includes marine invertebrates that live from the littoral zone to 500 m depth and not include meiofauna and parasitic groups. Correction for synonymous species names is incomplete. A database with species names can be found at the Greenland Institute of Natural Resources (Grønlands Naturinstitut).
Pisces (fish)	app. 150*	Nielsen & Bertelsen, 1992. *The number includes species that are found regularly.
Aves (birds)	58*	Salomonsen, 1950; 1967; 1990; Boertmann, 1994. *The number represents the number of birds that breed in Greenland.
Mammalia (mammals), terrestrial	8	Vibe, 1981; 1990.
Mammalia (mammals), marine	22	Vibe, 1981; 1990.
<b>Total number of species</b>	<b>&gt;9400</b>	

### 3.1. Terrestrial species diversity

#### 3.1.1. Fungal diversity

A fungus is made up of chains of tubular cells called hyphae (Petersen, 1995). Hyphae grow, branch and form a mycelium. Fungal cells do not contain chlorophyll; hence, they are not able to produce ATP and must acquire it by diffusion across hyphae walls. At given points in their life cycle, many fungi produce fruiting bodies composed of hyphae that are threaded together. Sexual reproduction and spore formation take place in the fruiting body. Spores are small, typically one- or few-celled dispersal units that usually are wind dispersed. Spores germinate to form a new mycelium. Wind dispersed fungal spores are extremely effective dispersal units and fungi are therefore found practically anywhere where life is possible: everywhere in the landscape; under anoxic conditions in food and organisms; in the coldest Arctic; in lakes and in the sea.

Fungi can be divided into four ecological categories (Petersen, 1995):

*Decomposers* (saprotrophs) decompose already dead organic matter. Some decompose leaves, stems and needles (the genera *Mycena*, *Typhula*, *Clitocybe*, *Collybia* and ), while others de-

compose manure (species of *Coprinus*, *Panaeolus* and *Psilocybe* along with a number of species from the order Pezizales) and plant remains in the ground (genera such as *Clavaria* and *Agaricus*). Some decomposers damage damp wood in houses (*Antrodia* sp., *Coniophora* sp. and *Dacryomyces stillatus*).

*Parasites* exploit living organisms, which they either weaken or kill. Examples include the sac fungi *Lachnellula willkommii*, which kills or deforms larch trees, and *Armillaria lutea*, which kills spruce and birch. *L. willkommii* is particularly harmful for the plantations in South Greenland. The genus *Phellinus* attacks and weakens birch and alder. One of the fungi that parasitize other fungi is *Collybia cirrata*, which grows on toadstools.

*Predators* exploit living organisms that they actively catch and kill. The only known example in Greenland among the basidiomycetes is the species *Hohenbuehelia fluxilis*. It apparently lives as a saprophyte on dead willow branches, but also catches nematodes with its mycelium and in this way acquires a surplus of nitrogen.

*Mutualists* encompass a large group of fungi that live in a mutualistic symbiosis, usually with living autotrophes. Some of the most important ones create ectomycorrhizae. The genera *Laccaria*, *Amanita*, *Lactarius*, *Boletus*, *Russula*, *Cortinarius*, *Inocybe* and *Hebeloma* are common ectomycorrhizae forming genera. They form ectomycorrhizae with many plant species including, willow (*Salix*), birch (*Betula*), green alder (*Alnus crispa*), mountain avens (*Dryas*) and viviparous knotweed (*Polygonum vivparum*). The fungal mycelia have very large surface areas, much larger than that of host plant roots and hairs. The plants receive water and several minerals through the fungi, which also protect the roots to some degree from damaging attacks by other fungi. In return, the fungi receive sugar and various vitamins from their host. Another important group of mutualists is the group of fungi that live in symbiosis with green algae and blue-green algae, i.e. form lichens or are lichenized (see section 3.1.2. on lichens).

There are close to 100,000 known species of fungi in the world and it is estimated that at least 1,400,000 species exist that have not been described. This makes fungi the second largest group of organisms, with arthropods being the largest (Hawksworth, 1992). The kingdom of true fungi (Mycota) includes the phyla Chytridiomycota, pin moulds (Zygomycota), sac fungi (Ascomycota) and basidiomycete fungi (Basidiomycota). The majority of recent studies on Greenland's fungi have focused on the sac fungi (cup fungi order and lichens) and basidiomycetes.

When macrofungi, microscopic species and parasites are included, it is estimated that there are around 1,600 fungi in Greenland (Knudsen, 1999). In the discussion of species that follows, only the basidiomycetes are included. Most of these groups are being prepared for a fungus guide in English. Basidiomycota has three subphyla: Uredomycotina (smuts, etc.); Ustomycotina and Hymenomycota. Fungi in the first two subphyla have basically not been collected or studied since the beginning of the 20th century, hence the concentration on Hymenomycota.

718 species in 160 genera have been recorded for the subphylum Hymenomycota, which includes the edible fungi. Genus and species numbers have been taken from an unpublished survey by Knudsen (1990) supplemented with Elborne & Knudsen (1990), Knudsen, Hallenberg & Mukhin (1993) and additions made by T. Borgens (table 4). The orders Tricholomatales and Cortinariales are by far the most species-rich with 189 and 131 species, respectively. Both orders predominantly encompass fungi with a stalk and a cap with lamellae on the underside. A few smaller genera are also included, such as *Flagelloscypha*, which look like small, hanging bowls, lack lamellae and grow on dead wood. Most of the species in the order Tricholomatales are decomposers. The species *Armillaria lutea*, however, is a dangerous para-

**Table 4.** Overview of the number of species within the orders of Hymenomycota (a subphylum of the Basidiomycota).

Taxonomic group (Order)	Number of species	Source/Comments
Dacryomycetales 1 family, 3 genera	5	Torkelsen (revision in prep.). The number of species is expected to increase. Form small, spherical, or scabby, gelatinous fruiting bodies.
Tremellales 1 family, 1 genus	2	Torkelsen (revision in prep.). The number of species is expected to increase. Form small, spherical, or scabby, gelatinous fruiting bodies.
Auriculariales 2 families, 4 genera	7	Knudsen et al., 1993; Torkelsen (revision in prep.). The number of species is expected to increase. Form small, spherical, or scabby, gelatinous fruiting bodies.
Ceratobasidiales 1 family, 1 genus	1	Petersen & Hauerslev, unpubl. Belong to the form group "bark fungi". Usually form a scabby cover on dead wood and are particularly common in South Greenland. "Bark fungi" species can usually only be distinguished by using a microscope.
Tulasnellales 1 family, 1 genus	5	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. Belong to the form group "bark fungi".
Botryobasidiales 1 family, 2 genera	6	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. Belong to the form group "bark fungi".
Cantharellales 3 families, 7 genera	18	Petersen & Hauerslev, unpubl. Belong to the shape group "club fungi". Included in this order is the genus <i>Multiclavula</i> .
Gomphales 1 family, 2 genera	4	Petersen & Hauerslev, unpubl. The species have club or coral shaped hymenia.
Hericiales 4 families, 5 genera	6	Petersen & Hauerslev, unpubl.; Knudsen et al., in prep. Except for the genus <i>Lentinellus</i> , which resembles a mushroom, all genera have a spiked hymenium. They are predominantly rare but are widely distributed in Greenland.
Russulales 1 family, 2 genera	57	Knudsen & Borgen, 1983; Knudsen et al., in prep. Many unsolved problems especially among the species of <i>Russula</i> . An increase in the number of species is expected. The genus <i>Russula</i> particularly has many edible species. The following orders of fungi are almost exclusively cap fungi: Russulales, Cortinariales, Tricholomatales, Entolomatales, Pluteales, Amanitales, and Agaricales. They are not necessarily related even though the fruiting bodies are divided into cap, lamellae and stalk.
Polyporales 2 families, 5 genera	5	Petersen & Hauerslev, unpubl. Belong the shape group "pore fungi", which grow on living or dead, most commonly thick wood. Most of the species are only found in South Greenland.
Coriolales 2 families, 2 genera	2	Petersen & Hauerslev, unpubl. The species have a labyrinth or pore type hymenium and have the same living conditions and distributions as pore fungi.
Fometopsidiales 1 family, 2 genera	3	Petersen & Hauerslev, unpubl. The species have a labyrinth or pore type hymenium and have the same living conditions and distribution as pore fungi.
Thelephorales 1 family, 5 genera	16	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. Most of the species resemble "bark fungi" in appearance and living conditions.
Cortinariales 3 families, 12 genera	131	Senn-Irlet, 1995; Borgen, 1998a; 1998b; Gulden, in prep.; Vesterholt, in prep. <i>Rozites caperatus</i> is a valuable edible fungus. There are a number of poisonous fungi especially in the genera <i>Inocybe</i> and <i>Galerina</i> . With the ongoing revisions of the species-rich and difficult genera <i>Cortinarius</i> , <i>Galerina</i> , <i>Inocybe</i> and <i>Hebeloma</i> , it can be expected that the number of species will increase tremendously.
Boletales 4 families, 6 genera	20	Knudsen & Borgen, 1987. The genus <i>Leccinum</i> is associated with birch and widely distributed in Greenland. They are good and easily recognizable edible fungi. In addition to several species of <i>Boletus</i> , the genera <i>Paxillus</i> and <i>Coniophora</i> also belong to this order.
Tricholomatales 3 families, 33 genera	189	Elborne, unpubl.; Borgen & Arnolds, in press. The majority of Greenland's samples have been revised, including the genera: <i>Hygrocybe</i> (26); <i>Clitocybe</i> (18); <i>Mycena</i> , <i>Hemimycena</i> , <i>Mycenella</i> (44); and <i>Omphalina</i> (23). The genus <i>Lepista</i> contains valuable edible fungi. There are many poisonous species of the genus <i>Clitocybe</i> (Borgen, 1993).
Entolomatales 1 family, 3 genera	40	Noordeloos, 1984. The genus <i>Entoloma</i> with 36 species has been revised by Noordeloos, 1984. There are many poisonous species of the genus <i>Entoloma</i> .
Pluteales 1 family, 1 genus	4	Knudsen & Borgen, 1987; Knudsen et al., in prep.
Amanitales 1 family, 1 genus	9	Knudsen & Borgen, 1987; a few additions by Tulloss, unpubl. In Greenland, the genus <i>Amanita</i> only contains the subgenus <i>Amanitopsis</i> - Grisettes, which are all good edible fungi (Borgen, 1993).

Table 4. (continued)

Taxonomic group (Order)	Number of species	Source/Comments
Agaricales 4 families, 16 genera	74	Knudsen & Borgen, 1987; Rald, unpubl.; Watling, unpubl.; Knudsen et al., in prep. Several of the genera, including <i>Psatyrella</i> and <i>Coprinus</i> , are not well known in Greenland and an increase in the number of species should therefore be expected. The genus <i>Agaricus</i> contains valuable edible fungi species. They are usually rare but can be common inland (Borgen, 1983).
Melanogastrales 1 family, 1 genus	1	Knudsen et al., in prep. Belong to the form group "truffles". They form underground, knobby fruiting bodies where the spores are created. There are very few species of truffles in the Arctic since they are primarily spread when rodents consume the fruiting bodies. <i>Alpova diplophloeus</i> forms mycorrhizae with alder and are not uncommon.
Lacnocladiales 1 family, 2 genera	2	Petersen & Hauerslev, unpubl. Belong to the form group "bark fungi".
Hymenochaetales 4 families, 4 genera	9	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. The species resemble "bark fungi" or "pore fungi" and have the same living conditions and distribution.
Lycoperdales 2 families, 5 genera	22	Lange, 1948; 1976; 1987; 1990. Lange is currently revising the genus <i>Lycoperdon</i> and the number of species can be expected to rise from 7 to about 15 species. The species are edible when they are young (Borgen, 1993).
Schizophyllales 1 family, 4 genera	5	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. The species of this order resemble "bark fungi" in appearance, living conditions and distribution.
Aleurodiscales 3 families, 5 genera	7	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. Belong to the form group "bark fungi".
Stereales 2 families, 3 genera	7	Petersen & Hauerslev, unpubl. Belong to the form group "bark fungi".
Nidulariales 2 families, 3 genera	4	Lange, 1948. <i>Crucibulum leave</i> , among others, belongs to this order (Borgen, 1993).
Hyphodermatales 4 families, 7 genera	19	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. The species resemble "bark fungi" or "pore fungi" and have the same living conditions and distribution.
Xenasmatales 4 families, 8 genera	21	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. Belong to the form group "bark fungi".
Lindtneriales 1 family, 1 genus	1	Petersen & Hauerslev, unpubl. Belong to the form group "bark fungi".
Atheliales 1 family, 3 genera	8	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. Belong to the form group "bark fungi".
Phanerochatales 2 families, 3 genera	8	Petersen & Hauerslev, unpubl.; Knudsen et al., 1993. Belong to the form group "bark fungi".
<b>Total number of species</b>	<b>718</b>	

site on birch (*Betula pubescens*) and larch (*Larix*). Many species are common in Greenland, but wood dwelling species primarily grow in South Greenland. The order Cortinariales is primarily made up of mycorrhizae forming species. In addition, there are a few species of the order Cortinariales that are decomposers. Even though the order has the bulk of its distribution in South Greenland, many species are widely distributed. It is probably the least studied group of basidiomycete fungi in Greenland. Since several genera are very species-rich, especially *Cortinarius*, a rather large increase in the number of recorded species can be expected with an increased research effort.

### 3.1.1.1. Rare basidiomycete (*Basidiomycota*) fungi in Greenland

Despite inadequate research, difficulties in determining the frequency of occurrence of fungus species and other reservations, a very preliminary list of examples of fungi that presumably are rare in Greenland is given in table 5. The 13 rare species have been found once or just a few times in the same type of habitat in various well studied areas.

Five of the rare species, *Tricholoma atosquamosum*, *Cortinarius violaceus*, *Hydnum repandum*, *Phellinus cinereus* and *Bjerkandera adusta*, are associated with birch. Of these, the last three

**Table 5.** Overview of rare basidiomycete fungi (Basidiomycota).

Species	Habitat	Locality
<i>Camarophyllopsis foetens</i>	on grass heaths	Qassiarsuk
<i>Tricholoma atosquamosum</i>	under birch	Ivittuut
<i>Omphalina chlorocyanea</i>	on burn areas	Kangilineq (Paamiut)
<i>Entoloma vinaceum</i>	on dwarf-shrub heaths	Eqaluit (Paamiut)
<i>Ramicola haustellaris</i>	under birch	Narsarsuaq
<i>Gymnopilus fulgens</i>	at bog edges	Paamiut
<i>Cortinarius violaceus</i>	under birch	Qanassiassat
<i>Hydnum repandum</i>	in birch forest	Qinnqua (Tasermiut)
<i>Phellinus cinereus</i>	on living birch	Qinnqua (Tasermiut)
<i>Bjerkandera adusta</i>	on birch	Qinnqua (Tasermiut)
<i>Pteridomyces galzinii</i>	on ferns	Narsarsuaq
<i>Disciseda calva</i>	on sandy plains	Mestersvig
<i>Geastrum minimum</i>	among steppe vegetation	Kangerlussuaq

species are found only in Greenland's most developed and most valuable birch forest in the protected Qinnqua Valley by Tasermiut Fjord (map 14). These species can be considered vulnerable since the occurrence of well developed birch forest in Greenland is limited. *T. atosquamosum* and *C. violaceus* are rare worldwide and are on the Red Lists of many countries. *H. repandum*, *P. cinereus* and *B. adusta* are common in Denmark and are also found in mountainous birch forests in northern Scandinavia. Only the lushest birch growths in southern Greenland have similar conditions.

*Ramicola haustellaris* and *Pteridomyces galzinii* have also been found in birch forest, but are not necessarily associated with it. The former grows on dead wood and is either rare or overlooked in Scandinavia, but not yet Red listed. *P. galzinii* has been found growing on a fern. It is possibly the first find of this species outside of France, but it may easily have been previously overlooked.

*Camarophyllopsis foetens* is rare everywhere and is a good indicator of previously grazed fringe areas, whose rich fungal flora does not tolerate fertilizers or plowing.

*Disciseda calva* and *Geastrum minimum* are associated with steppe vegetation, which is widely distributed in continental areas in West, North and East Greenland. Since the fungi of these vegetation types have only been studied a couple of places in Greenland, more finds may be made eventually. Many finds should not be expected however, since the species are rare worldwide.

The remaining rare species are found in more common habitats. The species *Omphalina chlorocyanea*, *Entoloma vinaceum* and *Gymnopilus fulgens* are rare worldwide and only a few more finds in Greenland should be expected.

### 3.1.1.2. Species-rich fungus habitats

The greatest diversity of species is found in South Greenland, where at least 400 fungus species have been recorded in Qinnqua Valley by Tasermiut Fjord and around Narsarsuaq, as well as in Paamiut County, where almost just as many have been found. It is expected that the number of species found will increase with increased research effort.

Studies in Qinnqua Valley by Tasermiut Fjord, around Narsarsuaq and by Ellerslie Harbor east of Ivittuut indicate that the birch (*Betula pubescens*) scrub forests of southern Greenland house the largest number of species and without a doubt, have the greatest density of basidi-

omycete fungi (Knudsen, Elborne & Borgen, in prep.). 102 species alone have been found in direct association with birch as parasites and decomposers on trunks and branches, as decomposers on dropped foliage and twigs and as mycorrhizae (Elborne & Knudsen, 1990). Scrub forests with birch presumably house more than 200 species of basidiomycete fungi, with half of them not found anywhere else in Greenland.

Dwarf-shrub heath with dwarf birch (*Betula nana*) is another species-rich fungus habitat, especially in the fjords. Many edible fungi are found here, such as the species *Amanita fulva*, *A. mortenii* and *Rozites caperatus*, the genus *Leccinum* and the toadstool *Paxillus involutus*. Included are also a number of *Russula* and *Lactarius* species and several medium-sized species of *Cortinarius*.

Heaths of mountain avens (*Dryas*) are found on nutrient-rich substrates, especially inland. They have rich and diverse fungal communities that, at present, are scarcely known. Widespread heaths dominated by white Arctic bell-heather (*Cassiope tetragona*), with more or less uninvestigated fungal communities, are found in northern Greenland.

Since the 1960s, experimental plantations have been planted in Greenland, mostly in South Greenland (Narsasuaq, Qanassiassat and Tasermit Fjord by Kuussuaq). Siberian larch (*Larix sibirica*) from Ural and white spruce (*Picea glauca*), subalpine fir (*Abies lasiocarpa*) and lodgepole pine (*Pinus contorta*) from regions near the timberline in Alaska are doing very well. A number of mycorrhiza forming fungi have followed along, such as species of *Suillus*, the species *Gomphidius septentrionalis* and several medium-sized species of the order Cortinariales. Of the remaining species that form mycorrhizae with introduced tree species, are some that probably were present in Greenland beforehand (e.g., *Rozites caperatus*). It can be expected that several other species will colonize Greenland as the plantations mature.

### 3.1.2. Lichen diversity

The lichen phylum is made up of fungi that live in symbiosis with green algae (Chlorophyceae) or blue-green algae (Cyanophyceae). The symbiosis between the two partners is mutualistic. The lichen's fungal partner, or mycobiont, absorbs water and mineral nutrients, which are shared with the algal partner, or photobiont. In return, the photobiont photosynthesizes organic matter that is shared with the mycobiont. Together they form the lichen body where the fungus generally dominates and surrounds the alga, which is thereby protected from the sun and desiccation (Krog *et al.*, 1994).

Lichens are perennial and slow growing. They do not have roots and fluids are absorbed directly by the fungal tissue where it is also stored (Hansen, 1993b). In dry and sunny weather lichens lose water through evaporation and photosynthesis decreases with increasing desiccation. They can tolerate a high degree of desiccation and can survive in this state for several years. By drying out, lichens avoid ice formation within cells and can therefore tolerate very low temperatures (Hansen, 1978b). Water is reabsorbed very quickly after desiccation and photosynthesis and build-up of substances continues.

Lichens can reproduce sexually using spores and asexually by fragmenting into "lichen pieces" and specialized lichen parts (soredia and isidia). Dispersal is primarily wind born. The number of lichens that reproduce sexually generally decreases as one moves northward (Hansen, 1978b).

Lichens can be separated into groups based on morphology: fruticose (bushy), foliose (leafy) and crustose (encrusting), but there are also many transitional forms. Lichens are named after the fungal partner. Mycobiont species are generally only found in lichens, while the green algae (Chlorophyceae) and blue-green algae (Cyanophyceae) species also occur in free-living form (Raven *et al.*, 1986). Up to now, 114 mycobiont species have been found in Greenland,

100 ascomycetes (Ascomycota), 13 deuteromycetes (Deuteromycota) and a single basidiomycete (Basidiomycota) (Alstrup & Hawksworth, 1990).

Hansen (1993b) estimates that the number of lichens in Greenland is somewhere around 950 species. In the current review of the literature, approximately 930 species in about 170 genera were found (a database of these species can be found at the Greenland Institute of Natural Resources (Grønlands Naturinstitut)). Of course, name changes and synonymous names may occur. Currently, a more complete survey of Greenland's lichens is being put together using the lichen collection at the Botanical Museum, University of Copenhagen, Denmark (Hansen, pers. comm.). For a popular review of lichens see Hansen (1987b; 1995).

Lichens are found in all ice-free regions of the country and on nunataks. They grow on soil, cliffs and other bare surfaces. The combination of light, moisture, temperature and preferred lichen substrate, determines lichen distribution. Likewise, snow cover duration has an influence. Greenland's lichen species are categorized based on distribution patterns: circumpolar (distribution in the northern region of the globe); amph-Beringian (distribution in the area around the Bering Strait); amph-Atlantic (distribution on both sides of the Atlantic Ocean) and disjunct (distribution in Greenland and, for example, western North America). Distribution mapping of single species, however, is still too incomplete to place them in these groups (Hansen, 1987b). Many species in Southwest Greenland with an amph-Atlantic distribution are also found in Scandinavia (Dahl, 1950).

*Dactylina arctica* and *Usnea sphacelata* are among the species found in the High Arctic, but are rare in South Greenland (Christiansen, 1981). In the mountains the number of species decreases with increasing elevation. Only species that can tolerate the cold and drought conditions on wind blown peaks are found at the top (Hansen, 1991a). In places where strong winds dry out the lichens, the growth of fruticose lichens is particularly limited. The outermost coastal zone is almost free of lichens because sea ice clears away the majority of plant growth (Christiansen, 1981). However, one species, *Pyrenocollema halodytes*, grows on barnacles on the cliff coast on Qeqertarsuaq. This species is probably also present on coastal cliffs in Southwest and West Greenland (Hansen, 1995). Lichens are often pioneer species on bare cliffs and mountains. Crustiose lichens of the genus *Umbilicaria* are usually the first to become established and are the basis for the slow development of a foundation to which plants attach (Vevle, 1975). *Dibaeis baeomyces* grows in a pioneer fashion on bare soil along trails in dwarf-shrub heaths and fell-fields (Hansen, 1995). Species of the genus *Cladonia* are very prominent in protected localities that are covered with snow during the winter. Along with species such as *Flavocetraria nivalis* and *Stereocaulon alpinum*, they are an important food source for caribou. The genus *Stereocaulon* is equipped with green algae and blue-green algae. The blue-green algae make it possible for *Stereocaulon* species to absorb nitrogen from the air. They are among the fastest growing Arctic, fruticose lichens and together with species of the genus *Cladonia*, dominate areas that have been cropped by grazing caribou (Christiansen, 1981). Species that are characterized by growing on the bones of caribou, whales and other Arctic mammals include *Candelariella aurella*, *Caloplaca stillicidiorum*, *Xanthoria elegans*, *X. borealis* and *Physcia dubia* (Hansen, 1983b).

Birch and willow scrubs in southwestern Greenland are rich in lichens. There are numerous species of the genus *Cladonia*, along with many species of fast growing, and therefore very successful, foliose lichens (e.g., *Peltigera aphthosa*) (Hansen, 1987b). At least 100 species of lichen grow on trees, bushes and dwarf-bushes in Greenland. For example, birch (*Betula pubescens*) is covered by species such as *Melanelia septentrionalis*, *Cetraria sepincola* and *Vulpicida pinastri* (Hansen, 1987b).

It is not currently possible to give a summary of rare or endangered lichen species.

Lichens are used for research in various ways. Some function as indicators of the presence of certain metals. For example, it has been shown that the lichens *Umbilicaria lyngei*, *Pseudophebe pubescens* and *Lecanora polytropa* on Qeqertarsuaq, grow on surfaces with a high concentration of copper and will store the metal in high concentrations (Alstrup & Hansen, 1977). *Fulgensia bracteata* and *Vulpicida tilesii* are examples of lichens growing on steppes and in deserts that can be valuable indicators in geological research (Hansen, 1987b). For example, *V. tilesii* grows in areas with a limestone substrate.

Substances build up in foliage and lichens can be used for monitoring purposes. For example, lichens and mosses have been used to analyze the concentration of airborne metals around the now closed lead and zinc mine in Maarmorilik in Uummannaq County (Pilegaard, 1994). Certain lichens, due to their slow and ring-shaped growth, can be used to date (lichenometry) glacial advances and rock slides (Beschel, 1958; Hansen, 1987b).

### 3.1.3. Moss (Bryophyta) diversity

The phylum Bryophyta belongs to the plant kingdom. Mosses grow to a maximum height of 50 mm and lack true roots and actual vascular tissue in the stem. Most species have a stem and leaves and are fastened to the substrate with thin thread-like structures (rhizoids). Some species absorb moisture from the air, as lichens do, while others are aquatic. There are no marine algae and only a few species in the world can tolerate brackish water. Some species can tolerate desiccation for long periods of time. However, most species are poorly protected against drying out and the moss flora is usually most developed in shady, moist places.

The living habits of mosses indicate their pronounced ability to adapt to their environment and factors such as, unstable soil, shade and extreme cold. They can reproduce both sexually and asexually and are dispersed by the wind (Mogensen, 1987). The balance between vegetative propagation via fragmentation and sexual reproduction via spores varies among species. The type of reproduction that dominates is dependent upon the species' ability to disperse leaf fragments in both male and female plants, and spore capsules in female plants, which disperse further with decreasing size (Holmen & Mogensen, 1981). With vegetative propagation reproductive parts drop off from the apical ends, or large moss fragments sever from the plant and fasten to new substrates. In sexual reproduction, gametes are produced on male and female plants and fertilization occurs when they are wet. Spores are formed in capsules that develop on the female plant after fertilization. Traits of the capsules are used to discriminate among Bryophyte families, genera and species.

Mogensen (1987) mentions four groups of mosses in Greenland, of which granite mosses (Andreaea) and sphagnum mosses (Sphagnaceae) each contain related genera, and liverworts (Hepaticeae) and true mosses (Musci) are categorized according to their morphology. Presently, a description of the mosses of Greenland, Arctic Canada and Alaska is being completed. Up to now, work on seven of the 44 families that were known at the beginning of the project in 1985, has been completed (see Long, 1985; Crum, 1986; Murray, 1987). There are approximately 20,500 moss species in the world, of which 600 of them are found in Greenland (table 6). The mosses in Greenland are dominated by foliose mosses, which account for over 440 species (Mogensen, 1987). Granite mosses, sphagnum mosses and liverworts comprise 10, 27 and 135 species, respectively (Mogensen, 1987). Within the seven families that have been worked on, the following rare species can be mentioned: *Oligotrichum falcatum*, *Andreaea alpina*, *A. heinemannii*, *Sphagnum pylaesii*, *S. lenense*, *S. obtusum* and *Lyellia aspera*.

The distribution of mosses, in comparison to that of vascular plants, seems to be more dependent on substrate than on climate, and the difference in the number of species between north and south is not noticeably big (Holmen & Mogensen, 1981). Sphagnum moss (Sphagnaceae) species and representatives of the genus *Andreaea* show a clear affinity for acidic gneiss. Species with a preference for acidic substrates that are very common in the southern

**Table 6.** Overview of the number of mosses (*Bryophyta*) in Greenland.

Taxonomic group	Number of Species	Source
Granite mosses ( <i>Andreaea</i> )	10	Mogensen, 1987
Spagnum mosses ( <i>Spagnum</i> )	27	Mogensen, 1987
True mosses ( <i>Musch</i> )	>440	Mogensen, 1987
Liverworts ( <i>Hepaticae</i> )	135	Mogensen, 1987
<b>Total number of species</b>	<b>app. 612</b>	Mogensen, 1987

regions, but in the north seek out the higher precipitation areas along the coast, include *Sphagnum lindbergii* and *Kiaeria glacialis*. Dung mosses are associated with carcasses and the manure of the larger animals and are placed in a group of their own, the family Splachnaceae. They require a substrate that is rich in phosphate and nitrate. The southern species include *Hedwigia ciliata*, *Mnium hornum*, *Rhizomnium magnifolium*, *Grimmia elatior*, *Rhodobryum roseum*, *Fontinalis antipyretica*, *Antitrichia curtipendula* and *Sphagnum papillosum* (Holmen & Morgensen, 1981). *Psilopilum cavifolium*, *Ceratodon purpurius*, *Polia filum*, *Stegonia latifolia* and *Aloina brevirostre* are among the pioneer species (Mogensen, pers. comm.).

### 3.1.4. Vascular plant (*Tracheophyta*) diversity

The majority of Greenland is in the Arctic and can be divided into three plant regions: a Low Arctic, a Middle Arctic and a High Arctic, as illustrated on map 7 (Bay, 1996). The categorization of plant regions is based on the coincidence in distribution of a number of plant species and the presence of characteristic plant communities. Each region, Low, Middle and High Arctic, is divided into an outer coastal (oceanic) and an inland (continental) zone. Only a few inland areas in South Greenland are not included in the Arctic. These Subarctic regions can be recognized by the presence of birch forest and a number of boreal species that, in Greenland, are only known from these areas. The relatively warm summers in the inland regions provide suitable conditions for this lush and, for Greenland, very unique flora and vegetation.

During the last ice age, the majority of Greenland was covered by ice. Only a few areas in West, East and North Greenland were ice-free and functioned as refuges where the most cold-tolerant species could survive. Most of Greenland's current flora has colonized the area after the end of the Ice Age about 10,000 years ago. The plants immigrated primarily along three routes. Low Arctic species have immigrated either to West Greenland from eastern North America or to Southeast Greenland from Eurasia via the North Atlantic islands, and have since then spread to other parts of the country. High Arctic species have primarily immigrated to western North Greenland from the northernmost regions of Canada. Only a few species from Eurasia have colonized Middle and High Arctic Greenland. Today, these conditions are reflected in plant distribution patterns. Some species have been in Greenland for many years, while others, such as alpine avens (*Geum rossii*) and Sudetic lousewort (*Pedicularis sudetica* ssp. *albolabiata*), probably immigrated much later and still have not spread to all suitable habitats.

#### 3.1.4.1. Phytogeography

Greenland's vascular plants are categorized into six main geographical units: 50% are circumpolar, 20% are western, 12% are amphi-Atlantic, 12% are eastern, 6% are endemic and under 1% are amphi-Beringian. Circumpolar species are found all the way around the Arctic Ocean, while eastern and western species are mainly distributed in North America and Eurasia, respectively. Amphi-Atlantic species are distributed from eastern North America, across Greenland and Iceland into western Eurasia. Amphi-Beringian species are primarily distributed around the Bering Strait and stretch toward the east to High Arctic Canada and North Greenland.

Table 7. Greenland's vegetation zones.

Zone	Geographic distribution	Dominant plant community	Zonal plant community	Indicator species	Vascular plant diversity/ Vascular plant cover (%)
<b>High Arctic</b>					
Oceanic	North of 80° N	Herb community	Herb community	<i>Ranunculus sabinei</i>	40/0-5
Continental	North of 80° N	Fell-field <i>Dryas</i> community <i>Salix arctica</i> community <i>Carex stans</i> bog	<i>Dryas</i> community	<i>Erysimum pallasii</i>	120/0-10
<b>Mid Arctic</b>					
Oceanic	70°-76° N	<i>Cassiope</i> heath Fell-field <i>Salix arctica</i> snow-bed (only E. Grl.)	<i>Cassiope</i> heath	<i>Carex ursina</i>	
Continental	E. Grl.: 70°-80° N W. Grl.: 70°-72° N 76°-70° N	<i>Cassiope</i> heath <i>Betula nana</i> heath (south of 75° N) <i>Salix arctica</i> snow-bed (only E. Grl.) <i>Carex stans</i> grassland <i>Carex stans</i> bog	<i>Cassiope</i> heath	<i>Ranunculus nivalis</i> <i>Draba alpina</i> <i>Epilobium arcticum</i>	250/5-50
<b>Low Arctic</b>					
Oceanic	60°-70° N	<i>Empetrum</i> heath Mixed dwarf-shrub heath <i>Salix herbacea</i> snow-bed <i>Salix glauca</i> scrub <i>Veronica</i> herb-slope <i>Eriophorum scheuchzeri</i> bog	<i>Veronica alpina</i> herb-slope	<i>Empetrum nigrum</i> <i>Salix herbacea</i> <i>Ledum groenlandicum</i> <i>Diapensia lapponica</i> <i>Gentiana nivalis</i>	325/10-50
Continental	E. Grl.: 63°-66° N W. Grl.: 63°-70° N	<i>Betula nana</i> - <i>Ledum palustre</i> heath <i>Vaccinium uliginosum</i> - <i>Salix glauca</i> heath <i>Salix glauca</i> scrub <i>Salix supina</i> steppe <i>Eriophorum scheuchzeri</i> bog	<i>Betula nana</i> heath	<i>Betula nana</i> <i>Carex supina</i> <i>Salix glauca</i> <i>Ledum palustre</i>	
<b>Subarctic</b>					
Continental	60°-63° N	<i>Betula pubescens</i> forest Low Arctic, continental vegetation types	<i>Betula pubescens</i> forest	<i>Betula pubescens</i> <i>Sorbus groenlandica</i> <i>Streptopus amplexifolius</i>	350/10-75

Greenland's location between Eurasia and the continent of North America, the fact that it is an island and its proximity to North America are reflected in the regional assemblages of its flora. There are generally more western than eastern species in Greenland and the only region where the number of eastern species is greater than the number of western species, is in Southeast Greenland.

Greenland's plant species are not distributed equally throughout the country. Like all regions in the northern hemisphere, the number of species present decreases when moving from south to north. In South Greenland there are approximately 350 species, in Middle Arctic areas there are approximately 200 species and in North Greenland, only 120 species are present (table 7). All plant groups exhibit this tendency. For example, there are 25 species of woody plants in South Greenland, but they are gradually reduced to three species in North Greenland.

The most important geographical boundaries for plants are the boundaries between Subarctic and Low Arctic, Low Arctic and Middle Arctic and Middle Arctic and High Arctic, located at approximately 60°, 70° and 80° N, respectively (map 7). In addition to the number of species decreasing markedly at these boundaries, the Subarctic-Low Arctic boundary is marked

by the disappearance of birch forest and several boreal species. At the Low Arctic-Middle Arctic boundary many Low Arctic and High Arctic species reach their northern and southern borders and vegetation characteristics change. The lush scrub and herb-slopes, which are characteristic elements of the Low Arctic landscape, disappear and white Arctic bell-heather (*Cassiope tetragona*) and mountain avens (*Dryas* sp.) heaths dominate Middle Arctic regions. The plant cover becomes significantly more open in High Arctic regions. In the coastal regions of North Greenland the landscape is very open with a total plant cover of less than a couple of percent. In these coastal areas there are no woody plants, aquatic plants, pteridophytes or sedges. A summary of vegetation zones is given in table 7.

Arctic plants are characterized by being adapted to low annual and summer temperatures, a short growing season and the effect of the midnight sun, which allows for photosynthesis for long, uninterrupted periods during the summer. In addition to having relatively few species, Arctic flora is characterized by having few endemic genera and species. The life forms that occur are limited and only very few annual species are present. The total number of plant species in the entire Arctic is around 2,000. The most species-rich area in the Arctic is in Chukotka in the eastern part of Siberia. Compared to Arctic regions in Alaska, Canada and Russia, Greenland's flora, with nearly a fourth of the species present, can be termed relatively species-rich.

#### 3.1.4.2. *The status of Greenland's flora*

Botanical research in Greenland started about 250 years ago when Paul Egede began collecting plants in West Greenland. With the establishment of Grønlands Botaniske Undersøgelse (GBU) [Botanical Survey of Greenland] in 1962, a massive study of Greenland's flora and vegetation began. Many of the difficult to reach areas in North and Northeast Greenland were first subjected to systematic botanical studies within the last few decades (Fredskild, 1996b). Several guides to Greenland's vascular plants have been made (Böcher *et al.*, 1968; 1978; Feilberg *et al.*, 1996; Foersom *et al.*, 1997).

Presently, 515 indigenous vascular plant species are known from Greenland. With the two species alpine avens (*Geum rossii*) and chickweed wintergreen (*Trientalis europaea*), which were found for the first time in Greenland in the 1990s, the total number of indigenous vascular plant species is 513 (Bay, 1993). In addition, a new species, *Festuca edlundiae*, described by Aiken, Consaul & Lefkovich (1995) and a variety of alpine fescue, *Festuca brachyphylla* var. *groenlandica*, that has been elevated to the species level, *Festuca groenlandica*, are added to this figure (Frederiksen, 1982). Greenland's vascular plants include 21 aquatic plant species (discussed in section 3.2.2) and a single marine species, the sea-grass *Zostera maritima*. The vascular plants of Greenland also include a number of species that are thought to have been introduced by Norsemen or other travelers (Pedersen, 1972), but they have only spread to the natural vegetation to a small degree and are not included in the total number of species.

Table 8 gives a summary of the distribution of indigenous species among families. Figures for the number of endemic and rare species are also given. Taxonomy and nomenclature primarily follow those given by Böcher, Fredskild, Holmen & Jakobsen (1978). Additions and changes were made according to Feilberg (1984), Bay (1992), Fredskild (1996a) and Mossberg & Stenberg (1994). There are 64 known vascular plant families in Greenland. The majority of species are distributed among only a few families and many families that are species-rich in boreal regions, are only represented by one or a few species in Greenland. In comparison to North America, one of the biggest floristic differences is that the family Fabaceae is only represented by one species in Greenland, while in Arctic North America, this family is represented by the large genera *Oxytropis* with 14 species and *Astragalus* with 11 species. The reason for this is that species in the Fabaceae family have large, smooth seeds, which are not easily dispersed across large marine areas by birds or wind. The only species of this family in Greenland is the beach pea (*Lathyrus maritimus*), whose seeds, in contrast to most of the

**Table 8.** Distribution of indigenous species in plant families. Additions and minor changes were made according to Feilberg (1984), Bay (1992) and Fredskild (1996). The total number of species, number of endemic species, number of rare endemic species and number of other rare species are given. Numbers for endemic species are from a revision by Böcher et al. (1959).

Taxonomic group (family)	Number of species	Number of endemic species	Number of rare endemic species	Number of other rare species
Lycopodiaceae (Clubmoss family)	5			
Selaginellaceae (Spike-moss family)	2			1
Isoëtaceae (Quillwort family)	2			1
Equisetaceae (Horsetail family)	5			1
Ophioglossaceae (Adder's tongue family)	6			3
Athyriaceae (Lady fern family)	7			2
Thelypteridaceae (Curley grass family)	1			
Aspidiaceae	6			
Aspleniaceae (Spleenwort family)	1			
Polypodiaceae (Staghorn fern family)	1			1
Cupressaceae (Redwood family)	1			
Ranunculaceae (Buttercup family)	16			4
Rosaceae (Rose family)	25	1	1	9
Crassulaceae (Stonecrop family)	4			1
Saxifragaceae (Saxifrage family)	18	1		1
Pomaceae (Apple family)	1			
Fabaceae (Legume family)	1			
Onagraceae (Evening primrose family)	7			
Haloragaceae (Water-milfoil family)	2			1
Hippuridaceae (Mare's-tail family)	1			
Papaveraceae (Poppy family)	1			
Brassicaceae (Cabbage family)	38			4
Violaceae (Viola family)	4			
Droseraceae (Sundew family)	1			1
Geraniaceae (Geranium family)	1			1
Polygalaceae (Milkwort family)	1*			1
Callitrichaceae (Water-starwort family)	4			

*Table 8. (continued)*

Taxonomic group (family)	Number of species	Number of endemic species	Number of rare endemic species	Number of other rare species
Cornaceae (Dogwood family)	2			1
Apiaceae (Umbel family)	2			
Saliaceae	5			
Betulaceae (Birch family)	4			
Polygonaceae (Buckwheat family)	5			
Portulacaceae (Purslane family)	1			
Chenopodiaceae (Goosefoot family)	1			1
Caryophyllaceae (Pink family)	33			3
Primulariaceae	4			3
Plumbaginaceae (Leadwort family)	2			
Pyrolaceae (Wintergreen family)	3			
Ericaceae (Heather family)	10			3
Vacciniaceae	4			1
Empetraceae	1			
Diapensiaceae	1			
Gentianaceae (Gentian family)	6			2
Menyanthaceae (Buckbean family)	1			
Polemoniaceae (Phlox family)	1			1
Boraginaceae (Borage family)	1			
Lamiaceae (Mint family)	1			
Scrophulariaceae (Figwort family)	17			4
Lentibulariaceae (Bladderwort family)	4			1
Plantaginaceae (Plantain family)	1			
Rubiaceae (Madder family)	4			1
Caprifoliaceae (Honeysuckle family)	1			
Campanulaceae (Bellflower family)	2			
Asteraceae (Aster family)	68	18**	11	13
Liliaceae (Lilly family)	2			

Table 8. (continued)

Taxonomic group (family)	Number of species	Number of endemic species	Number of rare endemic species	Number of other rare species
Convallariaceae	1			
Iridaceae (Iris family)	1	1	1	1
Orchidaceae (Orchid family)	5			1
Juncaceae (Rush family)	18			4
Cyperaceae (Sedge family)	59			16
Poaceae (Grass family)	71	6	3	14
Potamogetonaceae (Pondweed family)	8			4
Juncaginaceae (Arrowgrass family)	1			
Sparganiaceae (Burreed)	2			
<b>Total number of species</b>	<b>515</b>	<b>27</b>	<b>16</b>	<b>106</b>

\* The origin of the species is doubtful. The only known sample may have been brought in from Norway with materials for pressing plants.

\*\* Includes 15 apomictic species of the genus *Hieracium*.

species in the family, can tolerate being submerged in salt water for long periods of time and hence, can be dispersed by ocean currents.

The most species-rich families are Poaceae and Asteraceae with 71 and 68 species, respectively. The family Cyperaceae follows close behind with 59 species, of which the genus *Carex* has 47 species and is the most species-rich plant genus in Greenland. Other species-rich genera include *Draba* (19 species), *Hieracium* (18 species), *Saxifraga* (16 species) and *Ranunculus* (12 species). The other large families are Brassicaceae (38 species), Caryophyllaceae (33 species), Rosaceae (25 species), Saxifragaceae (18 species), Juncaceae (18 species) and Ranunculaceae (16 species). The families Ericaceae, with only 10 species in Greenland, and Salicaceae are the most dominant families in Greenland in terms of vegetation biomass. The majority of the remaining families are only represented by one or a few species. These include families that have many representatives in the regions just south of the Arctic. For example, the families Boraginaceae, Lamiaceae and Apiaceae are only represented by, respectively, one, one and two species in Greenland. Conifers, which dominate in the temperate plant regions just south of the Arctic and make up the timberline in both North America and Russia along the transition between the northern boreal zone and the Arctic, are only represented by one species in Greenland, prostrate juniper (*Juniperus communis* ssp. *alpina*). This species is never a dominant element of Low Arctic vegetation.

#### 3.1.4.3. Evaluation of species status

Species status has been evaluated and the definition of endangered, vulnerable and rare species generally follow international guidelines (IUCN; Løjtant & Worsøe, 1993). The evaluation is based on the number of collections housed in the Greenlandic herbarium at the Botanical Museum, University of Copenhagen, Denmark. It holds about 90% of all vascular plant collections from Greenland. These materials are the basis for *Grønlands Flora* [Greenland's Flora] (Böcher *et al.*, 1978) and for phytogeographical publications covering different parts of Greenland (Feilberg, 1984; Bay, 1992; Fredskild, 1996a). Therefore, nothing is usually known about the population's size at individual collection sites.

*Vulnerable species* are defined in this report as species with only very few occurrences, i.e. less than 5, usually within a very limited area of Greenland. Future human activities in the area of their limited distribution will be a threat to their survival in Greenland. They can be expected to become endangered and thus in danger of disappearing in the near future, if threats to their survival are not eliminated.

Species found on less than approximately 20 localities are termed rare in accordance with the definition of *rare species* used by the collaborative work "Conservation of Arctic Flora and Fauna" (Talbot *et al.*, 1997). They are composed of few and/or small populations that are not threatened or vulnerable at this point in time, but that may become so.

#### 3.1.4.4. Endemic taxa

Table 9 gives an overview of Greenland's endemic taxa, with designations of their occurrence in floristic districts, the number of localities where they are known to grow and their status. On the basis of similarities in distribution types, Greenland's vascular plants are categorized into several floristic provinces, which are divided into floristic districts (Böcher *et al.*, 1959). These categorizations have been revised based on new information gathered within the last few decades (Bay, 1997a). The most marked changes are: 1) the division of each of the North and South Greenland provinces into two districts; 2) the new demarcation of districts at the transition from Low to Middle Arctic areas in West Greenland; 3) the splitting of districts in Northwest and Northeast Greenland and 4) the expansion of Low Arctic inland regions in West and East Greenland. See map 8 for the categorization of floristic provinces and districts used in the analysis of the occurrence of endemic species.

Böcher, Holmen & Jakobsen (1959) calculated the number of taxa endemic to Greenland to be 35, one of these being at the subspecies level (*Potamogeton pusillus* L. ssp. *groenlandica* (Hagstr.) Böch.) and one at the variety level (*Calamagrostis lapponica* (Wbg.) Hartm. var. *groenlandica* Lge.). Since then, some of the endemics listed have been found outside of Greenland or their classification as a separate taxon has been brought into question, thus reducing the number of endemics. *Potentilla ranunculus*, *Antennaria sornborgeri* and *A. glabrata* have been found in North America and can no longer be considered endemic to Greenland. Phytogeographical research within the past few years has shown that the taxonomic classification of some species is not warranted. Because of this, the following species, which were originally considered endemics of Greenland, are no longer included: *Draba gredinii* and *Braya intermedia* (Bay, 1992); *Gentiana amarella* (Feilberg, 1984) and *Puccinellia porsildii* (Fredskild, 1996). Four new endemic taxa have been added since the original evaluation: *Draba sibirica* (Pall.) Thell. ssp. *arctica* Böcher (Böcher, 1974); *Festuca groenlandica* (Frederiksen, 1982); *Potentilla stipularis* var. *groenlandica* (Gelting, 1934) and the generic hybrid x *Ledodendron vanhoeffeni* (synonym: *Rhododendron vanhoeffeni* Abrom.) (Dalgaard & Fredskild, 1993).

Today 32 taxa are considered to be endemic to Greenland (table 9). The endemics comprise about 6% of the flora indigenous to Greenland. The occurrence of endemics in floristic provinces and districts is shown on map 25 and the endemic taxa are commented in table 10. Of the endemic species, 15 belong to the hawkweed genus (*Hieracium*). Hawkweeds are apomictic, i.e. they produce seeds without pollination, which explains the high number of endemic species. For some of these, only a few collections within a limited area have been made and out of 16 endemic taxa, species of the hawkweed genus comprise 11 of them. The rare endemic species include *Calamagrostis hyberborea*, *C. poluninii*, *Potentilla rubella*, *Sisyrinchium groenlandicum* and *Puccinellia rosenkrantzii*. Point maps of endemic species can be found at the Greenland Institute of Natural Resources (Grønlands Naturinstitut).

Some of the Arctic endemics have large parts of their distribution in Greenland. This is true for species such as three-flowered lychnis (*Melandrium triflorum*) and *Puccinellia bruggemanni*.

**Table 9.** Overview of Greenland's endemic vascular plant species, subspecies, varieties and generic hybrids. Status and occurrence in floristic districts and the number of localities where the species grows are given. Revised by Böcher et al. (1995).

Species	Occurrence in floristic districts (districts are shown on map 8)	Number of known localities in Greenland where the species grows	Status: vulnerable (V)
<i>Antennaria affinis</i>	CS, SWn, CW, NWso	57	
<i>Antennaria hansii</i>	S, CS, CW, CWs+n, SEs+n	99	
<i>Antennaria intermedia</i>	S, CS, SW, CW, NWso	81	
<i>Calamagrostis hyperborea</i>	S, CS	20	
<i>Calamagrostis poluninii</i>	CS, CW	18	
<i>Elymus trachycaulus</i> ssp. <i>virescens</i>	S, CS, SWs, SEs	46	
<i>Festuca groenlandica</i>	S, SW, CWm+n, NWsi, SE, CE	47	
<i>Hieracium acranthophorum</i>	CS, SWn	2	V
<i>Hieracium amitsokense</i>	S, CS	27	
<i>Hieracium angmagssalikense</i>	SEm	1	V
<i>Hieracium devoldii</i>	CS	1	V
<i>Hieracium eugenii</i>	CS	1	V
<i>Hieracium hyparcticum</i>	S, CS, SW, CWs+m, SEs+m, CEs	335	
<i>Hieracium ivigtutense</i>	SWs, CWs	9	
<i>Hieracium lividorubens</i>	S, CS, SW	88	
<i>Hieracium musartutense</i>	CS	1	V
<i>Hieracium nepiocratum</i>	S	1	V
<i>Hieracium rigorosum</i>	S, SWs, CWs	86	
<i>Hieracium scholanderi</i>	S, CS	2	V
<i>Hieracium stelechodes</i>	SEs	1	V
<i>Hieracium stiptocaula</i>	CS	4	V
<i>Hieracium sylowii</i>	S	1	V
<i>Potentilla rubella</i>	CEm+n1	12	
<i>Puccinellia groenlandica</i>	SW, CW, NWsi	32	
<i>Puccinellia rosenkrantzii</i>	NWso	4	V
<i>Saxifraga nathorstii</i>	CEm+n1	98	
<i>Sisyrinchium groenlandicum</i>	CWs+m	9	V
<b>Subspecies</b>			
<i>Draba sibirica</i> ssp. <i>arctica</i>	CEm	25	
<i>Potamogeton pusillus</i> ssp. <i>groenlandicus</i>	S, CS, SW, CW, NWsi, SEs	75	
<b>Varieties</b>			
<i>Calamagrostis lapponica</i> var. <i>groenlandica</i>	CWm+n	28	
<i>Potentilla stipularis</i> var. <i>groenlandica</i>	CEm+n1	8	V
<b>Hybrids</b>			
x <i>Ledodendron vanhoeffnii</i>	CWs+m	8	V

**Table 10.** Comments on endemic vascular plants.

Species	Comments
<i>Antennaria affinis</i>	This species grows on dry calcium substrates and is known from a number of localities in Low Arctic West Greenland - from Ameralik to Upernavik and inland by Tunungdliarfik.
<i>Antennaria hansii</i>	Is present in the southern parts of Low Arctic Greenland northward to southern Qegertarsuaq/Disko Island and Tasiilaq/Ammassalik. It grows on dry substrates in heaths and on herb-slopes.
<i>Antennaria intermedia</i>	The species is present on lush herb-slopes in West Greenland between Nunap Isua/Cape Farewell and Nuussuaq.
<i>Calamagrostis hyperborea</i>	Grows on moist substrates in scrubs, mostly inland in South Greenland.
<i>Calamagrostis lapponica</i> var. <i>groenlandica</i>	Is found on nutrient-poor, moist substrates in heaths and scrubs in the continental inland in West Greenland between the fjord Evighedsfjorden and the bay Sydostbugten.
<i>Calamagrostis poluninii</i>	Found in dry, wind blown areas and grasslands in the inland region between South Greenland and the Bay Sydostbugten.
<i>Draba sibirica</i> ssp. <i>groenlandica</i>	The species has a very limited distribution in the belt that crosses Jameson Land in central East Greenland.
<i>Elymus trachycaulus</i> ssp. <i>virescens</i>	The species is found in birch and willow scrubs in continental southern Greenland and towards the north to Southern Isortoq and Skjoldungen.
<i>Festuca groenlandica</i>	The species is present in the entire Low Arctic region of Greenland.
<i>Hieracium acranthophorum</i>	Known only from two places: inland in South Greenland and by Northern Isortoq.
<i>Hieracium amitsokense</i>	Known from a number of places in South Greenland.
<i>Hieracium angmagssalikense</i>	Found once by Tasiilaq/Ammassalik.
<i>Hieracium devoldii</i>	One find continental South Greenland.
<i>Hieracium eugenik</i>	One find continental South Greenland.
<i>Hieracium hyparcticum</i>	Grows in dry grasslands, scrubs and on herb-slopes and is widely distributed in Low Arctic Greenland.
<i>Hieracium ivigtutense</i>	A few occurrences in Southwest Greenland.
<i>Hieracium lividorubens</i>	Grows in birch scrubs, heaths and on herb-slopes in southeastern Greenland.
<i>Hieracium musartutense</i>	One find continental South Greenland.
<i>Hieracium nepiocratum</i>	One find in South Greenland.
<i>Hieracium rigorosum</i>	Widely distributed in South and West Greenland. Grows in scrubs and on herb-slopes.
<i>Hieracium scholanderi</i>	Two finds in South Greenland.
<i>Hieracium stelechodes</i>	Only one find in Dronning Maries Valley in Southeast Greenland.
<i>Hieracium stiptocaulae</i>	Is known only from South Greenland.
<i>Hieracium sylowii</i>	Is known only from South Greenland.
<i>Potamogeton pusillus</i> ssp. <i>groenlandicus</i>	Grows in nutrient-rich water in lakes and ponds in the majority of Low Arctic Greenland.
<i>Potentilla rubella</i>	A few occurrences inland in central East Greenland between Jameson Land and Kuhn Island. The species may not be endemic to Greenland, it is also found in the central Arctic in Russia.
<i>Potentilla stipularis</i> var. <i>groenlandica</i>	The Greenlandic endemic variety is currently only known from a few places in Greenland. The species' closest relatives are found in eastern Russia. Is an Arctic endemic species.
<i>Saxifraga nathorstii</i>	Grows on open, moist substrates in central East Greenland.
<i>Sisyrinchium groenlandicum</i>	Is only known from the interior of the fjords Godthåbsfjord and Søndre Stroemfjord.
<i>Pucinellia groenlandica</i>	Grows in central West Greenland.
<i>Pucinellia rosenkrantzii</i>	Is only known from a few localities on Nussuaq in Disko Bay. Is only found on mud volcanoes.
x <i>Ledodendron vanhoeffnii</i>	This generic hybrid is a continental species from West Greenland.

### 3.1.4.5. Rare, non-endemic species

An overview of the distribution of rare, non-endemic species is given in table 11. An indication of whether a species is rare in its distribution outside of Greenland is given for species that are rare in Greenland. For rare species that also are rare at the global level, Greenland's populations are of international importance for the preservation of the species. This category is comprised of species whose main distributions are in Greenland. Point maps of rare, non-endemic species can be found at the Greenland Institute of Natural Resources (Grønlands Naturinstitut).

For the following rare species, which have sporadic distributions in the whole or part of their range, their occurrence in Greenland is an important part of their total distribution. Sardinian buttercup (*Ranunculus sabinei*) and *Puccinellia bruggemanni* are both High Arctic endemic species that are rare and very rare, respectively, over their entire range. *Taraxacum hyparcticum* is an endemic of the Arctic and fringed gentian (*Gentiana detonsa*) is an Arctic-boreal endemic. Both are rare in their respective ranges. Alpine avens (*Geum rossii*) is very rare outside of the Rocky Mountains and areas near the Bering Strait.

When excluding the Subarctic region of the country, there is a clear tendency for rare species to be present at higher frequencies in continental Greenland than in areas near the coast (map 26). Boreal species, which are only found in South Greenland, have their northern boundary in the summer-warm regions of South Greenland, where the climate during the growing season is reminiscent of the conditions that these species grow under further south. In the northern part of their distribution, there is a clear tendency for Low Arctic species to be found in inland areas in other, more protective plant communities than further south. Highland rush (*Juncus trifidus*), which is common in fell-fields and dry grassy vegetation with a thin snow cover during the winter, is found only on herb-slopes and other protective plant communities in its northernmost occurrences.

**Table 11.** Overview of the Greenlandic and global distribution and status of rare, non-endemic taxa. Five types of distribution are categorized as follows: circumpolar (circ); western (west); eastern (east); amphi-Atlantic (amph-atl); and amphi-Beringian (amph-ber). Status: vulnerable (V) and threatened (T).

Taxonomic group (family)	Species	Occurrence in floristic districts (districts are shown on map 8)	Number of localities where the species is known to grow	Global distribution	Status
Selaginellaceae	<i>Selaginella rupestris</i>	CS	1	west	V
Isoëtaceae	<i>Isoetes lacustris</i>	S	6	east	V
Equisetaceae	<i>Equisetum hiemale</i>	SEm	1	circ	V
Ophioglossaceae	<i>Botrychium simplex</i>	S, SE	4	amph-atl	
Ophioglossaceae	<i>Botrychium multifidum</i>	S	1	circ	V
Ophioglossaceae	<i>Ophioglossum azoricum</i>	NEs	2	east	V
Athyriaceae	<i>Cystopteris montana</i>	S, CS, SWn	5	circ	
Athyriaceae	<i>Athyrium filix-femina</i>	S, CS	2	circ	V
Polypodiaceae	<i>Polypodium virginianum*</i>	S	5	west	
Ranunculaceae	<i>Ranunculus cymbalaria</i>	CWs+m	4	west	
Ranunculaceae	<i>Ranunculus sabinei</i>	NWn, N, DN	23	west	
Ranunculaceae	<i>Ranunculus auricomus</i>	NEs, CEm+n1	22	east	
Ranunculaceae	<i>Anemone richardsonii</i>	CWs+m, SWs	21	west	
Rosaceae	<i>Rubus chamaemorus</i>	S, SWs	12	circ	
Rosaceae	<i>Rubus saxatilis</i>	S, SEs	2	east	V

Table 11. (continued)

Taxonomic group (family)	Species	Occurrence in floristic districts (districts are shown on map 8)	Number of localities where the species is known to grow	Global distribution	Status
Rosaceae	<i>Geum rivale</i> **	NEs	1	east	V
Rosaceae	<i>Geum rossii</i>	CEn2	1	amph-ber	V
Rosaceae	<i>Potentilla ranunculus</i>	S, SWn, CWn, SEs, NWso	21	west	
Rosaceae	<i>Alchemilla vestita</i>	S, CWs	19	east	
Rosaceae	<i>Alchemilla wichurae</i>	S, SEm	8	east	
Crassulaceae	<i>Sedum acre</i>	SEm	7	amph-atl	
Saxifragaceae	<i>Chrysosplenium tetrandrum</i>	CEm	3	circ	V
Saxifragaceae	<i>Parnassia kotzebuei</i>	CS, CWn, NWso	14	west	
Haloragaceae	<i>Myriophyllum spicatum</i> ssp. <i>exalbescens</i>	S, CS, CW	20	west	
Brassicaceae	<i>Erysimum pallasii</i>	NWn, CN	19	circ	
Brassicaceae	<i>Cakile edentula</i> ssp. <i>edentula</i>	S	1	west	V
Brassicaceae	<i>Rorippa islandica</i>	CS, CWm	6	circ	
Droseraceae	<i>Drosera rotundifolia</i>	S, CS, SWs, CWs	17	circ	
Geraniaceae	<i>Geranium sylvaticum</i>	S	6	east	
Polygalaceae	<i>Polygala serpyllifolia</i>	SEs	1	east	V
Cornaceae	<i>Cornus canadensis</i>	S, CWs	7	west	
Chenopodiaceae	<i>Atriplex longipes</i>	S, CWs	1	east	V
Caryophyllaceae	<i>Cerastium arvense</i>	SWs	1	circ	V
Caryophyllaceae	<i>Spergularia canadensis</i>	CWm	1	west	V
Caryophyllaceae	<i>Sagina nodosa</i>	S, CS	16	east	
Primulariaceae	<i>Primula egaliksensis</i>	CS, CWs+m	11	west	
Primulariaceae	<i>Androsace septentrionalis</i>	NWn	1	circ	V
Primulariaceae	<i>Trientalis europaea</i>	CS	1	circ	V
Ericaceae	<i>Arctostaphylos uva-ursi</i> ssp. <i>coactilis</i>	CWm	13	west	
Ericaceae	<i>Andromeda polifolia</i> s.l.	S, SW	5	west	
Vacciniaceae	<i>Vaccinium myrtillus</i>	S, SEs	2	east	
Gentianaceae	<i>Gentiana detonsa</i>	S, CWm+n, CEm+n1	23	east	
Gentianaceae	<i>Gentiana amarella</i> ssp. <i>acuta</i>	S, CWs, CEs	8	west	
Polemoniaceae	<i>Polemonium boreale</i>	CEm, NEm	16	circ	
Scrophulariaceae	<i>Pedicularis groenlandica</i>	SWs	1	west	T***
Scrophulariaceae	<i>Pedicularis capitata</i>	NWn, CN	11	west	
Scrophulariaceae	<i>Pedicularis langsдорffii</i> ssp. <i>arctica</i>	NWn	5	west	
Scrophulariaceae	<i>Pedicularis sudetica</i> ssp. <i>albolabiata</i>	NWn	4	west	locality threatened ****
Lentibulariaceae	<i>Utricularia intermedia</i>	S, SWs, CWm+n	15	circ	
Rubiaceae	<i>Galium boreale</i>	CS	1	circ	V
Asteraceae	<i>Taraxacum hyperacticum</i>	NWn, N, CN	11	west	
Asteraceae	<i>Matricaria maritima</i> ssp. <i>phaerocephala</i>	CEm	12	circ	

Table 11. (continued)

Taxonomic group (family)	Species	Occurrence in floristic districts (districts are shown on map 8)	Number of localities where the species is known to grow	Global distribution	Status
Orchidaceae	<i>Amerorchis rotundifolia</i>	CS, CWs+m	7	west	
Juncaceae	<i>Juncus gerardii</i>	CS	1	east	V
Juncaceae	<i>Juncus ranarius</i>	S, CS, CWs+m, NEs	17	circ	
Juncaceae	<i>Juncus alpinus</i> ssp. <i>nodulosus</i>	S, CS, CWs+m	25	circ	
Juncaceae	<i>Luzula wahlenbergii</i>	CEn1	10	circ	
Cyperaceae	<i>Eriophorum spissum</i>	S	1	west	V
Cyperaceae	<i>Eleocharis palustris</i>	CS	3	circ	V
Cyperaceae	<i>Eleocharis uniglumis</i>	CS	1	circ	V
Cyperaceae	<i>Eleocharis quinqueflora</i>	S, CS, CWm, NEs	18	amph-atl	
Cyperaceae	<i>Carex chordorrhiza</i>	S, CEm	4	circ	V
Cyperaceae	<i>Carex disperma</i>	S	1	circ	V
Cyperaceae	<i>Carex trisperma</i>	S	2	west	V
Cyperaceae	<i>Carex machenziei</i>	S, CS	7	circ	
Cyperaceae	<i>Carex abdita</i>	S, CS	7	west	
Cyperaceae	<i>Carex salina</i>	S, CS, CWS	6	amph-atl	
Cyperaceae	<i>Carex lyngbyei</i>	S, CS	2	circ	V
Cyperaceae	<i>Carex buxbaumii</i>	CS	3	amph-atl	V
Cyperaceae	<i>Carex magellanica</i>	S, CS, SWs, CWs	16	circ	
Cyperaceae	<i>Carex panicea</i>	S, CS	19	east	
Cyperaceae	<i>Carex vaginata</i>	CEn1	1	circ	V
Cyperaceae	<i>Carex viridula</i>	S, CS	6	west	
Poaceae	<i>Danthonia spicata</i>	CS	1	west	V
Poaceae	<i>Puccinellia laurentiana</i>	CWs	1	west	V
Poaceae	<i>Puccinellia bruggemanni</i>	N, NEn, CE	15	west	
Poaceae	<i>Catabrosa aquatica</i>	S, CWs	6	east	
Poaceae	<i>Arctophila fulva</i>	SWs	8	circ	
Poaceae	<i>Dupontia fisheri</i>	NWn, CEn1	5	circ	
Poaceae	<i>Agrostis scabra</i> var. <i>septentrionalis</i>	S, CS	11	west	
Poaceae	<i>Agrostis stolonifera</i>	S, CS, CWn	13	circ	
Poaceae	<i>Agrostis gigantea</i>	S, CS	5	circ	
Poaceae	<i>Hierochloë odorata</i>	CS	1	circ	V
Poaceae	<i>Elymus violaceus</i>	S, CS, SWs, CWm+n	17	west	
Potamogetonaceae	<i>Potamogeton natans</i>	CS	1	circ	V
Potamogetonaceae	<i>Potamogeton praelongus</i>	CWm, CEm	2	circ	V
Potamogetonaceae	<i>Potamogeton perfoliatus</i>	CEm	1	circ	V
Potamogetonaceae	<i>Zostera maritima</i>	CWs	6	circ	

\* Feilberg (1984) shows that the samples from Greenland belong to the North American species *P. virginianum* and not the Eurasian species, *P. vulgare*.

\*\* *Geum rivale* is also found on a lush herb-slope in the city of Julianehåb. It is thought to have been introduced.

\*\*\* The place where *P. groenlandica* grows is close to Nuuk and is a popular resort area. Furthermore, a school camp is located there.

\*\*\*\* The *P. sudetica* ssp. *albolabiata* population just west of Qaanaaq is threatened because an inevitable expansion of the city will wipe it out.

#### 3.1.4.6. *Distribution of endemic and rare species in floristic provinces*

Both endemic and rare species are most common in areas of the country that generally have the highest species diversity, i.e. the southernmost part of Greenland and the southern districts in West and East Greenland (maps 25 and 26). The majority of species occur inland. Boreal species have their northernmost occurrence in the inland regions of South Greenland where summertime temperatures are similar to those further south. In addition, there is a high occurrence of rare species in Northwest Greenland and central East Greenland where North American and Eurasian species have their most eastern and western distributions, respectively.

#### 3.1.4.7. *Threats of human induced changes to Greenland's vascular plant diversity*

Greenland's environment is generally only slightly influenced by human activities that are, or may become, a threat to the existence of endemic and rare plant species. Only areas in the immediate vicinity of cities and settlements show signs of being affected by human activity. Two rare species are directly threatened by human activities (map 27). *Pedicularis groenlandica* is only known from one locality in the fjord Eqaq near Nuuk. It is a popular and easily accessible resort area and since the plant is attractive and decorative, it is threatened not only by wear and tear, but also by picking. In the Thule District, a large population of Sudetic lousewort (*Pedicularis sudetica* spp. *albolabiata*) is found just outside of Qaanaaq. It is one of only four known localities in Greenland and an inevitable expansion of the town will wipe out the population.

Large areas of South Greenland are markedly affected by sheep grazing, hay harvesting and plowing. Additionally, there are areas where raw materials prospecting and extraction occur or have occurred.

Currently, only limited threats to plant populations exist. However, an increase in raw materials prospecting and extraction and increased tourism with many hikers would change this and may become actual threats within the next century. The only example of a species becoming extinct in Greenland in recent times is the loss of *Cirsium helenoides*, which, for unknown reasons, disappeared before 1960 from its only known place of occurrence by the valley Bjørnedal in Arsuk Fjord (Pedersen, 1972).

Many of the rare species occur in inaccessible areas that so far have not been influenced by human presence. These are not under immediate threat, but if human activities are commenced, the species will become endangered. Some species that are viewed as recent colonizers and are widely distributed in neighboring areas, may spread in the coming decades to suitable areas in other parts of the country and hence, increase their population sizes. Examples of these include Sudetic lousewort (*Pedicularis sudetica*) in the Thule District, Canadian sand-spurry (*Spergularia canadensis*) in the Sisimiut Region, alpine avens (*Geum rossii*) in Lambert Land and capitate lousewort (*Pedicularis capitata*) in North Greenland.

#### 3.1.5. *Arthropod (Arthropoda) diversity*

The arthropod phylum (Arthropoda) is by far the most species-rich, not only in the animal kingdom, but among all groups of living organisms. Of the known number of species on earth, about 1.7 million (Kristensen, 1993), the arthropods make up approximately 70%. The insects alone, which have close to one million species, comprise more than 50% of all species.

In Greenland, 931 species of terrestrial and freshwater arthropods distributed among four classes have been found: crustaceans (Crustacea); centipedes (Chilopoda); insects (Insecta) and arachnids (Arachnida). An overview of the distribution of species within the four classes is given in table 12, while table 13 shows the number of species within several arthropod families. Greenland's terrestrial and freshwater arthropod fauna is poor in comparison to patterns further south. For example, in Greenland there are 672 known species of insects,

**Table 12.** Overview of Greenland's terrestrial and freshwater arthropods. Orders that exclusively contain introduced species are enclosed in parentheses.

Taxonomic group	Number of species
Class Crustacea; crustaceans	65
Subclass Phyllopoda; phyllopods	62
Order Anostraca; fairy shrimp	2
Order Notostraca; tadpole shrimp	1
Order Cladocera; water fleas	29
Subclass Ostracoda; ostracods	13
Subclass Copepoda; copepods	17
Subclass Malacostraca; malacostracans	3
Order Mysidacea; mysids	1
Order Amphipoda; amphipods	2
Class Chilopoda; centipedes	2
Order Lithobiomorpha; lithobiomorphs	2
Class Arachnida; arachnids	192
Order Araneae; spiders	64
Order Opiliones; daddy-long-legs/harvestmen	1
Order Acarina; mites	127
Class Insecta; insects	672
Subclass Apterygota; wingless insects	41
Order Collembola; springtails	41
Subclass Pterygota; winged insects	631
(Order Ephemeroptera; may flies	1)
(Order Orthoptera; grasshoppers, etc.	1)
(Order Dermaptera; earwigs	1)
(Order Dictyoptera; cockroaches and mantids	1)
(Order Psocoptera; book and bark lice	3)
Order Mallophaga; biting lice	43
Order Anoplura; sucking lice	5
Order Hemiptera; true bugs	37
Order Thysanoptera; thrips	5
Order Neuroptera; lacewings	3
Order Trichoptera; caddisflies	8
Order Lepidoptera; butterflies and moths	52
Order Siphonaptera; fleas	7
Order Diptera; flies, midges and mosquitoes	310
Order Hymenoptera; ants, bees, wasps and sawflies	88
Order Coleoptera; beetles	66
<b>Total number of species</b>	<b>931</b>

**Table 13.** Overview of the number of species in various arthropod families.

Taxonomic group (family)	Total number of species in the taxonomic group	Number of species out of the total that are introduced
Coleoptera (beetles)	66	34
Carabidae (ground beetles and tiger beetles)	4	-
Dytiscidae (predacious diving beetles)	2	-
Gyrinidae (whirlygig beetles)	1	-
Hydrophilidae (water scavenger beetles)	2	1
Staphylinidae (rove beetles)	14	2
Buprestidae (metallic wood-boring beetles)	1	1
Byrrhidae (pill beetles)	4	-
Dermestidae (skin beetles)	4	4
Lycidae (power-post beetles)	1	1
Anobiidae (furniture beetles)	2	2
Ptinidae (spider beetles)	3	3
Trogositidae (bark-gnawing beetles)	1	1
Malachiidae (soft-winged flower beetles)	1	1
Cucujidae (flat bark beetles)	1	1
Cryptophagidae (silken fungus beetles)	3	2
Coccinellidae (ladybugs)	2	2
Latridiidae (scavenger beetles)	5	3
Tenebrionidae (darkling beetles)	2	2
Cerambycidae (longhorned beetles)	7	7
Curculionidae (weevils and snout beetles)	5	-
Scolytidae (bark beetles)	1	1
Hymenoptera (ants, bees, wasps and sawflies)	88	
Tenthredinidae (tenthredinid sawflies)	6	
Ichneumonidae (parasitic wasps)	60	
Braconidae (braconid wasps)	10	
Cynipidae (gall wasps)	1	
Chalcididae (chalcidid wasps)	8	
Proctotrupidae (proctotrupid wasps)	1	
Apidae (bees)	2	
Siphonaptera (fleas)	7	
Pulicidae	2	
Vermipsyllidae (carnivore fleas)	1	
Ceratophyllidae	4	
Diptera (mosquitoes, midges and flies)	312	
Suborder Nematocera	176	
Trichoceridae (winter crane-flies)	4	
Tipulidae (crane-flies)	11	
Culicidae (mosquitoes)	2	
Simuliidae (black flies)	5	
Ceratopogonidae (biting midges)	5	
Chironomidae (chironomid midges)	106	
Bibionidae (fever flies)	1	

*Table 13. (continued)*

Taxonomic group (family)	Total number of species in the taxonomic group	Number of species out of the total that are introduced
Mycetophilidae (fungus gnats)	18	
Sciaridae	21	
Cecidomyiidae (gall midges)	3	
Suborder Brachycera (horseflies, etc.)	7	
Empididae (dance flies)	5	
Dolichopodidae (thick-headed flies)	2	
Suborder Cyclorrhapha (houseflies, dungflies, etc.)	129	
Phoridae (phorid flies)	6	
Syrphidae (hover flies)	12	
Piophilidae (skipper flies)	4	
Sepsidae (black scavenger flies)	1	
Agromyzidae (leaf miner flies)	9	
Heleomyzidae (sun flies)	3	
Drosophilidae (pomace flies)	1	
Borboridae	5	
Ephydriidae (shore flies)	6	
Scathophagidae (dung flies)	6	
Anthomyiidae (root-maggot flies)	25	
Muscidae (true flies)	39	
Calliphoridae (blow flies)	6	
Oestridae (bot flies)	2	
Tachinidae (tachinid flies)	4	
Lepidoptera (butterflies and moths)	52	8
Pyralidae (pyralid moths)	8	3
Pterophoridae (plume moths)	1	
Tortricidae (bell moths)	3	
Olethreutidae	2	
Gelechiidae (gelechiid moths)	3	
Oecophoridae (codling moths)	3	2
Yponomeutidae (ermine moths)	2	
Scythrididae (flower moths)	1	
Tineidae (tineid moths)	3	
Lymantriidae (tussock moths)	1	3
Noctuidae (cutworm moths)	15	
Geometridae (inchworm moths)	5	
Nymphalidae (brush-footed butterflies)	2	
Lycaenidae (gossamer-winged butterflies)	2	
Pieridae	1	

Table 13. (continued)

Taxonomic group (family)	Total number of species in the taxonomic group	Number of species out of the total that are introduced
Trichoptera (caddisflies)	8	
Phryganeidae	1	
Limnephilidae	7	
Hemiptera (true bugs)	4	
Lygaeidae (seed bugs)	1	
Nabidae (damselfly bugs)	1	
Cimicidae (bedbugs)	1	
Miridae (mireid bugs)	1	
Homoptera (suborder)	29	
Cicadellidae (leafhoppers)	2	
Psyllidae	3	
Aphidoidea	21	
Coccoidea (scale bugs)	3	
Anoplura (sucking lice)	5	
Pediculidae	3	
Echinophthiriidae	2	
Mallophaga (biting lice)	43	
Liotheidae	7	
Trichodectidae	2	
Philopteridae	34	
Collembola (springtails)	41	
Hypogastruridae	11	
Onychiuridae	5	
Isotomidae	18	
Entomobryidae	2	
Sminthuridae	5	
Aracnida	60	
Theridiidae	3	
Erigonidae	33	
Linyphiidae	4	
Araneidae (orb-web spiders)	4	
Tetragnathidae	1	
Hahnidae	1	
Lycosidae (wolf spiders)	7	
Gnaphosidae	2	
Philodromidae	1	
Thomisidae (crab spiders)	2	
Dictynidae	2	
<b>Taxonomic group (family)</b>	<b>Total number of species in the taxonomic group</b>	<b>Number of species out of the total that are introduced</b>
Acarina, mites	127	

Table 13. (continued)

Parasitidae	17	
Ixodidae (hard-backed ticks)	1	
Trombidiidae	24	
Hydrachnidae	7	
Sarcoptidae	11	
Oribatidae (beetle mites)	60	
Phytoptidae	11	

while in Denmark, for example, there are almost 20,000. The occurrence of a relatively small number of Arctic insects and other arthropods is probably due to a number of reasons. Firstly, many ecological niches are not found north of the timberline. Secondly, the Arctic region had to be re-colonized after the last ice age. Thirdly, in order to survive, species have had to develop specific adaptations to Arctic conditions (Downes, 1962; 1964; 1965, Böcher, 1972b; Kevan & Danks, 1986b; Danks, 1981). Arthropod adaptations to Arctic regions include freeze-tolerance (Ring & Tesar, 1981; Kukal, 1991; Sømme & Block, 1991; Danks *et al.*, 1994), adaptations with regard to longevity and number of generations, a high degree of opportunism in relation to activity periods and longevity, the seeking out favorable microclimates and the ability to absorb and retain heat from the sun (Downes, 1964; Roland, 1982). The various insect groups have been able to meet the above criteria to different degrees and several orders are completely absent from the Arctic, while others have just a few representatives.

It is apparent for terrestrial invertebrates that only groups such as flies, midges and mosquitoes (Diptera), parasitic wasps (Ichneumonidae), springtails (Collembola), mites (Acarina) and spiders (Araneae), are relatively successful, while beetles (Coleoptera), for example, which are the largest of all groups of organisms (approximately a quarter of a million described species), only have 33 free-living representatives in Greenland. Numerous groups that are richly represented in tropical and temperate regions (*e.g.*, dragon flies, grasshoppers, ants and hornets) are completely absent from Greenland.

In general, information on the distribution of Greenland's arthropods is relatively incomplete because specimen collection has typically been scattered and random. Species diversity generally seems to decrease from south to north, or more precisely, from southwest to northeast. Of course there are exceptions and a few insect groups become more dominant the further north one goes. This is predominantly the case for dipterans (mosquitoes, midges and flies) and to a lesser degree, for lepidopterans (butterflies and moths), parasitic wasps and springtails. Arachnid groups, spiders and mites, are also relatively strongly represented in the northern Arctic.

There is a striking difference throughout Greenland, between insect diversity in oceanic areas with only a few hours of sunlight and few insects and continental areas with many hours of sunlight and far richer insect life.

Much of the insect fauna has distributions limited to the most climatically favorable region, i.e. the southern part of the west coast from the inland area near Nunap Isua, possibly a small section along the east coast, and a larger or smaller patch along the west coast northward to

Qeqertarsuup Tunua. This is true for most beetle species (map 28), the two cicada species, some lepidopterans (*e.g.*, *Eurois occulta*, whose distribution is shown on map 29) and several dipterans (flies, midges and mosquitoes) (*e.g.*, the annoying *Simulium vittatum*).

Some species have a very limited distribution in the mildest part of Subarctic Greenland. Norsemen may have introduced some of these, as indicated by the fact that they are only found in the central part of the Norse Eastern Settlement (*e.g.*, the true bug *Nabis flavomarginatus* and the rove beetle *Omalium excavatum*).

In 1917 a review of insects and arachnids was prepared (Henriksen & Lundbeck, 1997) that mentions 437 species of insects and 124 species of arachnids. Henriksen prepared the last complete review of Greenland's insects in 1939. Since then, the following groups of arthropods have been revised: freshwater entomostracans (Entomostraca) (Røen, 1962a; 1968; 1994; etc.); spiders (Brændegaard, 1946; Holm, 1967); mites (Haarløv, 1942); water mites (Hydracarina) (Lettevall, 1962); beetle mites (Oribatida) and springtails (Hammer, 1944); true bugs (Heteroptera) (Böcher, 1971; 1976) and aphids (Aphidoidea) (Lambers, 1952; 1960). The groups that especially need to be revised are dipterans (Diptera), parasitic wasps (Ichneumonidae, Braconidae), spiders (Araneae) and mites (Acarina), since they either have not been looked at since Henriksen (1939) or the later versions are outdated. A significant, unidentified sample of flies, mosquitoes, parasitic wasps, spiders and mites can be found at the Zoological Museum at the University of Copenhagen in Denmark. The identification and revision of these groups should bring about a significant increase in the number of known species.

#### 3.1.5.1. Crustaceans (Crustacea)

Crustaceans (Crustacea) are discussed in sections 3.2.3. and 3.3.3. since they are both limnic and marine.

#### 3.1.5.2. Millipedes and centipedes (Myriapoda)

Only one species of centipede, *Lamyctes fulvicornis* (order Lithobiomorpha, family Henicopidae) is known from a couple of localities in South Greenland (Böcher & Enghoff, 1984). An additional species, *Lithobius forficatus* (family Lithobiidae), has been found just once, indoors in South Greenland and was without a doubt introduced.

#### 3.1.5.3. Insects (Insecta)

The insect class (Insecta) dominates the arthropods with 672 species from 13 indigenous orders and 4 introduced orders. Greenland's beetles (order Coleoptera) were revised recently (Böcher, 1988b). The genus *Micralymma*, a rove beetle (Staphylinidae) genus, is treated by Schiödte (1857). Aspects of the biology and development of predacious diving beetles (Dystiscidae) has been studied by Madsen (1959), Røen (1981) and Jeppesen (1986). In all, 66 beetle species are known from Greenland and 33 of them can be regarded as native species, although Norsemen may have introduced a few of them. Species that are known only from the fossil record (from Norse culture layers) are not included. All of the undoubtedly introduced species associated with humans, such as longhorned beetles (Cerambycidae), can only live indoors, especially in food, wheat and timber stores, where they can be damaging. One species, the rove beetle *Atheta groenlandica* (Mahler, 1988), is possibly endemic since, up to this point, it has only been found in Greenland.

From a zoogeographical perspective Greenland's beetle fauna is notable in two respects: 1) it is mainly made up of species that have a relatively southern (boreal) distribution outside of Greenland and 2) the majority of species are Palaearctic (European), with only one species that is undoubtedly of North American origin (*Arctobyrrhus (Tylicus) subcanus*). These peculiar conditions have been zealously discussed for over 100 years (*e.g.*, Jensen, 1928; Brændegaard, 1946; Lindroth, 1957; Böcher, 1988a; 1988b; 1992-93; Downes, 1988). Coope (1979;

1986) has proposed the hypothesis that the invasion occurred via pack ice from northwestern Europe during the warming of the climate at the closure of the late glacial age. Map 28 shows the number of beetle species in each of Greenland's zoogeographical regions. The number of beetle species decreases only slightly towards the north along the southern half of the west coast, but decreases sharply from the southern tip northward along the east coast (Böcher, 1988).

The order Hymenoptera is a species-rich order in the Arctic and is composed of 88 species in Greenland. Parasitic wasps comprise 60 of the species, with the family Ichneumonidae being richly represented. Parasitic wasps are parasitoids, i.e. they lay their eggs in other insects, which the larvae parasitize and eventually kill. The largest species live in and off of butterfly larvae. Aside from one study on bumblebees (Bombinae), the biology and ecology of hymenopterans in Greenland is completely unknown. Probably none of the species have been introduced. One of Greenland's two species of bumblebee, *Bombus hyperboreus*, is a nest parasite on the most common species, *B. polaris*. The female enters the nest of *B. polaris* and kills the queen, after which *B. polaris* workers "slave" for the foreign female and raise her sex-specific offspring (Pape, 1983). This association is also known from Canada and Scandinavia.

Fleas (Order Siphonaptera) are temporary bloodsuckers on mammals and birds. In Greenland, seven flea species occur that parasitize on humans, Arctic foxes, ermines, Arctic hares, lemmings, waterfowl, gulls and passerine birds (Holland, 1985). Flea larvae normally live in waste material at the bottom of animal dens and bird nests. The larvae of *Hoplopsyllus glacialis* live temporarily on the coats of Arctic hares (Freeman & Madsen, 1949). The Eskimos did not originally have fleas, and human fleas (*Pulex irritans*) were introduced to Greenland with the arrival of the Europeans.

Dipterans (Order Diptera), comprised of mosquitoes, midges and flies, are without comparison, the most important insect order in the Arctic, both with respect to the number of species and to production. About 310 species have been recorded in Greenland. Midge larvae (Chironomidae) feed on organic detritus in all types of fresh water, in brackish water and in moist soils. Midges make up the most successful insect group in the Arctic and are represented by approximately 106 species in Greenland. Many midges are highly specialized for living in the Arctic. For example, they have multi-year larval stages and morphological and behavioral reductions as adults (Oliver, 1968; Downes, 1965; Danks, 1981). Only two species of mosquito (Culicidae) have been recorded in Greenland (Nielsen & Nielsen, 1966). At least one of the species, *Aedes nigripes*, has a distribution that covers almost all of Greenland and in most places occurs in extremely large numbers, posing a nuisance to humans and, for example, caribou. As with all bloodsucking mosquitoes, only the females bite. Female mosquitoes can survive and lay eggs without consuming blood, but in this case, will only produce very few eggs (Danks, 1981). Mosquito larvae live in stagnant water, while black fly larvae (Simuliidae) are found in flowing water. In many places in Greenland, the black fly species *Simulium vittatum* (called "the small fly with booties") is just as much of a nuisance as mosquitoes.

Among the true flies (Muscidae), which are comprised of 39 species, the genus *Spilogona*, whose larvae are mostly carnivorous, is particularly prevalent in the Arctic. The genus is represented by at least 13 species in Greenland. Flies play an important role as pollinators of Arctic plants. Blow flies (Calliphoridae) are common and noticeable in cities and settlements. The larvae live in rotting animal matter (e.g., meat and blubber waste) and can be a nuisance when they appear in meat that is hung to dry. This is taken into consideration in the domesticated reindeer industry and animals are only slaughtered after the evening frost has set in (P. Nielsen, pers. comm.).

A few fly species have been introduced to Greenland, for example, house flies (*Musca domestica*), little house flies (*Fannia canicularis*) and one fruit fly species, *Drosophila funebris*. Two

species of botfly that are associated with caribou, the reindeer botfly (*Oedemagena tarandi*) and the throat botfly (*Cephenemyia trompe*), were introduced to the Nuuk region in 1952 with the arrival of Norwegian domesticated reindeer (Vibe, 1981a). Unfortunately, the species are now widespread and well established with the caribou as host. Not only do the botflies stress the caribou and domesticated reindeer to the degree that their meat production is decreased significantly, the larvae of reindeer botflies also ruin harvested skins.

Of Greenland's dipterans, only two small families have been revised recently: leaf-mining flies (Agromyzidae) (Griffiths, 1966) and dung flies (Scathophagidae) (Pape, 1983). Hemmingsen & Jensen (1957) studied the variation in body length of the crane-fly *Tipula arctica* and Nielsen & Nielsen (1966) studied mosquitoes of Greenland. Vibe (1950; pers. comm.) has collected and identified a number of new species in comparison with those of Henriksen (1939) and these are included in the overview.

Greenland's butterflies and moths (Order Lepidoptera) have been revised by Wolff (1964). Fifty-two indigenous and eight introduced species have been recorded. As adults, lepidopterans usually feed on nectar from flowers and are important pollinators. The larvae are usually herbivorous, but the biology of Greenland's lepidopteran species has not been thoroughly studied. A single species of cutworm moth (Noctuidae), *Sympistis zetterstedtii*, seems to feed exclusively on the flowers of white dryads (*Dryas integrifolia*) (Philipp *et al.*, 1990; Böcher, 1996). The cutworm moth species *Eurois occulta*, and certain other lepidopteran species, sometimes occur in large numbers in southwestern Greenland. This can severely affect their host plants (grasses, birch, willow) and therefore must influence the sheep ranching industry. The distribution of *Eurois occulta* is shown on map 29.

The zoogeography of the lepidopteran fauna is thoroughly addressed by Downes (1966; 1988). Downes shows that the lepidopteran fauna of High Arctic North Greenland is identical to the fauna of High Arctic Canada (especially that occurring on Ellesmere Island) and that it has without a doubt colonized Greenland from there. Butterflies (Rhopalocera) are the most marked example. They decrease in both number of species and frequency of occurrence from north to south, indicating that they are adapted to continental, sunny, High Arctic conditions. Two of the species, the northern clouded yellow butterfly (*Colias hecla*) and the Arctic fritillary butterfly (*Clossiana chariclea*), are probably found throughout Greenland but become rare towards the south where they are only found at certain elevations in the mountains. A few other species are entirely restricted to High Arctic regions. This is true for species such as the polar fritillary butterfly (*Clossiana polaris*) and the high-mountain blue butterfly (*Plebejus glandon*), whose distributions are illustrated on map 29. The rest of the lepidopteran fauna forms a typical "island fauna" based upon random colonization from both North America and Europe. An actual Low Arctic lepidopteran fauna is missing in Greenland. *Eurois occulta*, however, is an example of a species that is restricted to Low Arctic-Subarctic West Greenland and southernmost East Greenland (map 29).

Dreisig (1981) studied the 24-hour summertime activity patterns of moths in Greenland. The High Arctic moth (*Gynaephora groenlandica*, Lymantriidae) has been the subject of comprehensive studies in North America (*e.g.*, Ryan & Hergert, 1977; Kevan *et al.*, 1982; Kukal, 1991; Kukal *et al.*, 1988; Kukal & Dawson, 1989). It is one of the most well-adapted Arctic insect species. For example, the very hairy larvae can live at least 13 years and can tolerate repeated freezing and thawing.

Eight lepidopteran species have undoubtedly been introduced from Europe and are pests in human habitations or storage facilities (*e.g.*, tineid moths (Tineidae)). Three species, the silver Y butterfly (*Autographa gamma*), the diamondback moth (*Plutella maculipennis*) and the rush veneer moth (*Nomophila noctuella*), are known long-distance colonizers that occasionally reach Greenland, but cannot survive the winter.

Caddisflies (Order Trichoptera) are represented by eight species in Greenland, which have been revised by Stoltze (1981). The Greenlandic caddisfly fauna is dominated by American species. None of the species are Palaearctic (European, Asian) and two species are Holarctic. Only one species is distributed throughout Greenland (*Apatania zonella*), the rest are restricted to the Low Arctic region. Caddisfly larvae live in fresh water. Most species live in hives built of materials such as plant remains or sand grains, and are characteristic for each species.

Three brown lacewing species (Order Neuroptera, Family Hemerobiidae) have been recorded from southern West Greenland. The larvae feed on aphids and other small insects.

Thrips (Thysanoptera) are very small insects that feed by sucking plant juices. The order has not been revised since Henriksen (1939) who calculated a total of five species belonging to the family Thripidae.

Hemipterans (Order Hemiptera) are composed of 37 species of true bugs, cicadas and various groups of aphids. Two of the four Greenlandic true bugs (Suborder Heteroptera) have had their biology and ecology studied (Böcher, 1971; 1972a; 1972c; 1975a; 1975b; 1976; 1978; 1990). The Arctic-alpine seed bug (*Nysius groenlandicus*) is dependent upon a warm, dry microclimate. It is distributed in almost all of Greenland, but is most numerous, and almost ubiquitous, in the inner, continental region. It feeds on dry seeds and fruits. *C. pullus* sucks plant juices. Only females of this species have been found in Greenland, suggesting that it is parthenogenic – a very rare phenomenon among true bugs. *Nabis flavomarginatus*, a predator, is only found in the Subarctic part of the country and may have been introduced by Norse immigrants. Bed bugs (*Cimex lectularius*), which reside indoors and suck blood from humans, were introduced from Europe.

The suborder Homoptera is represented in Greenland by a few species of leafhoppers (Cicadellidae), jumping plantlice (Psylloidea) and coccids (Coccoidea) and 21 species of aphids (Aphidoidea). No fewer than 16 new aphid species have been described from Greenland (Lambers, 1952; 1960). However, many of these have since been found in Arctic Canada and it is doubtful that they are endemic to Greenland. Most of the species feed on grasses, sedges and willows. Characteristic of Arctic aphid species is that there are very few generations per year and they do not change hosts during the life cycle, i.e. they complete their entire life cycle on the primary host (Downes, 1965). Hodkinson (1996) has studied the use of host plants (*Salix* sp.) along a climatic gradient (south-north) in Greenland for the species *Cacopsylla groenlandica*.

Sucking lice (Order Anoplura) are comprised of five species. The body louse (*Pediculus humanus*) appears to have been present originally with the Eskimo, while the crab louse (*Phthirus pubis*) was probably introduced with the Europeans, who possessed more body hair. Additionally, lice are found on Arctic foxes, seals and walruses.

Biting lice (Order Mallophaga), which exclusively are composed of external parasites on birds and mammals, have numerous representatives in the Arctic and comprise 43 species in Greenland. They feed on skin and feathers and many are pests on domestic animals. In Greenland, biting lice are probably found on all bird species, while trichodectid species (Trichodectidae) are found on dogs and ringed seals.

Springtails (Collembola) are a species-rich group in Greenland and the rest of the Arctic, and are important for decomposition in soil. They are comprised of 41 species in Greenland and are well studied on the basis of work done by Hammer (1938; 1944). Madsen (1936) also comments on the occurrence of springtails. A study of the 24-hour activity period of the species *Sminthurides malmgreni* has been carried out by Kristensen & Vestergaard (1975).

Several insect orders in Greenland are only represented by introduced species. This is true for book and bark lice (Order Psocoptera), which are represented by three families (Atropidae, Troctidae, Caeciliidae), each with one species. They are small, unimpressive and rather harmless species, found indoors where they feed on various organic remains. The oriental cockroach (*Blatta orientalis*, Order Dictyoptera, Family Blattidae) has been found just once. A couple of introduced specimens of the European earwig (*Forficula auricularia*, Order Dermaptera, Family Forficulidae) have also been recorded in Greenland. The greenhouse camel-cricket (*Tachycines asynamorus*, Order Orthoptera, Family Rhabdophoridae) has been found a single time in a conservatory. Only one species of mayfly, *Baetis tenax* (Order Ephemeroptera, Family Baetidae), has been found a couple of times in West Greenland.

#### 3.1.5.4. *Arachnids (Arachnida)*

Spiders (Araneae) are represented by 64 species and comprise a noticeable and relatively species-rich group in Greenland and the rest of the Arctic, where they probably are the most important insect predators. Greenland's spiders have been revised by Brændegaard (1946) and Holm (1967). Their biology and ecology however, are virtually unknown. Greenland's spider fauna is dominated by Holarctic (41%) and Nearctic (39%) species, with only 20% being Palaearctic species (Holm, 1967). Twenty-six species are limited to West Greenland and seven species are found only in East Greenland. None of the species are introduced. The taxonomic and zoogeographical overview should not be accepted unconditionally since Greenland's spider fauna needs a modern revision (N. Scharff, pers. comm., 1996).

Greenland has a single daddy-long-leg, also termed harvestmen, (Opiliones) species, *Mitopus morio* (Family Phalangidae), which has its distribution in the southern half of the country. Meinertz (1973) has documented the species' occurrence in Greenland. Daddy-long-legs, like spiders, are predacious.

Mites (Acarina) encompass 127 species and play an important role in Arctic soils, both in terms of quantity and number of species. Particularly prominent are the oribatid mites (Oribatei), whose biology, ecology and taxonomy have been researched by Hammer (1937; 1944; 1946). The mite fauna of the High Arctic has been studied by Haarløv (1942), who added a number of new species to the group. Lettevall (1962) has worked with Greenland's mite fauna and described a new species (*Lebertia groenlandica*) that presently is only known from hot springs by Qeqertarsuaq and should be considered endemic. In some years, some mites (*Pethaleus major*, *Bryobia* sp.) become pest species on hay crops in South Greenland (P. Nielsen, pers. comm.). The taxonomic groupings applied to the mites are simplified and outdated; most of the listed families should now have a suborder status.

#### 3.1.6. *Bird (Aves) diversity*

Several reviews of Greenland's birds have been made. The most important comprehensive work in recent times is that by Salomonsen (1950). Most recently, Boertmann (1994) has compiled an overview of all bird species observed in Greenland and has compared this to that compiled by Salomonsen (1967). Salomonsen (1990) provides descriptions of the appearances, distributions and breeding periods of Greenland's birds. Marine birds are discussed by Kampp (1981), and Low Arctic and High Arctic birds are discussed by Kampp & Kristensen (1981) and Meltofte (1981). Greenland's most common birds are described in field guides by Boertmann & Fjelså (1988) and Génsbøl (1996).

Sea and coastal areas have the richest bird fauna in Greenland, both with respect to the number of species and the number of individuals. In addition to breeding birds, many non-breeding bird populations from all over the North Atlantic are found here during the summer. The open water regions of Southwest Greenland are very important wintering areas that attract high concentrations of marine birds, Greenlandic birds, and quite a few birds from breeding populations in nearby Arctic nations (Kampp, 1981). In comparison to Arctic

regions in Alaska, Canada and Siberia, however, there is a noticeably poorly represented terrestrial and freshwater bird fauna, especially in West Greenland (Meltofte, 1985; Alerstam *et al.*, 1986). For example, there are 22 breeding species of waders and passerine birds on Baffin Island, while only nine species breed in West Greenland (Boertmann, 1998). The traditional explanation for this phenomenon is that species have not yet colonized the area since the last ice age 10,000 years ago. Another explanation however, may be that West Greenland is too far away from the northernmost feeding areas in southern Canada and birds can only reach West Greenland under very favorable conditions if they are to arrive in breeding condition (Alerstam *et al.*, 1986). However, immigration of birds to West Greenland from North America does occur, which supports the historical explanation. A good example is that of the Canada goose (*Branta canadensis*), which was a rare guest 30 years ago, but today is a common breeding bird over large areas of West Greenland (Boertmann, 1998).

235 bird species occur in Greenland. Approximately 58 of these are well-established breeding birds and around 17 species are encountered regularly during the summer, the rest are chance or very rare migrant guests (Boertmann, 1994). Of the 58 well-established breeding bird species, 37 are widely distributed on both sides of the Atlantic, 8 have their primary distribution in North America and 13 species are mostly distributed in Europe. Some species are associated with High Arctic Greenland, quite a few are associated with the Low Arctic region, others have small distributions within these climactic zones and only four species, red-throated divers (*Gavia stellata*), rock ptarmigans (*Lagopus mutus*), gyrfalcons (*Falco rusticolus*) and snow buntings (*Plectrophenax nivalis*), are found throughout Greenland (Boertmann, 1998).

The waterfowl family (Anatidae) is the most species-rich, while the alcid family (Alcidae) has the largest number of individuals. Since the last count (Salomonsen, 1967), the Barrow's goldeneye (*Bucephala islandica*) has disappeared. Ten new species of breeding birds have been recorded and some roving marine birds have become more common (Boertmann, 1994). There are no endemic species, but a few subspecies (dunlin (*Calidris alpina arctica*), an Iceland gull subspecies (*Larus glaucooides glaucooides*) and Greenland white-fronted goose (*Anser albifrons flaviostris*)), although they winter partly or completely outside of Greenland, breed only in Greenland. One mallard subspecies, *Anas platyrhynchos cornboschas*, and two rock ptarmigan subspecies, *Lagopus mutus captus* and *L. m. saturatus*, are truly endemic since they are not found outside of Greenland.

In addition to the red-throated diver (*Gavia stellata*), the great northern diver (*Gavia immer*) also breeds in Greenland. Great northern divers are typical in large lakes on the west coast northward to Qaanaaq and on the east coast up to Hochstetter Forland. In most places it breeds in small numbers (Boertmann, 1994).

Although the order Procellariiformes (petrels, fulmars, albatrosses) is represented in small numbers, the northern fulmar (*Fulmarus glacialis*) is the species most commonly seen in the waters surrounding Greenland. It breeds only a few places, but is very abundant in most of these places, which include Qeqertarsuup Kangerlua, Uummannaq and Qaanaaq. They nest on steep cliff walls in colonies that can contain thousands of pairs. Great shearwaters (*Puffinus gravis*) are the only breeding birds from the southern hemisphere that in smaller or larger numbers are summer/autumn guests in Greenland every year. They can be found northward to Sisimiut and Tasiilaq/Ammassalik. The species occurs along the coasts and sometimes in the larger fjords (Boertmann, 1994).

Of the species in the order Pelicaniformes (pelicans, cormorants, frigates), only great cormorants (*Phalacrocorax carbo*) breed in Greenland. They are common breeding birds from Maniitsoq to Upernavik, south of which they are more sporadically distributed. Great cormorants have shown a marked increase in success in several areas in the last few years (Boertmann &

Mosbech, 1997). Northern gannets (*Sula bassana*) are regular guests in Greenland in June-September, most often in the region from Qaqortoq to Nuuk. Their closest breeding sites are in Iceland and Newfoundland (Boertmann, 1994).

Waterfowl (Anatidae) include swans, geese and ducks. Six goose species breed on the west coast or in the High Arctic region. All of the species are increasingly successful, with the exception of the white-bellied brant (*Branta bernicla hrota*) (Boertmann, 1994; pers. comm.). The number of snow geese (*Anser caerulescens*) has increased since the middle of the 1970s and the species has expanded its distribution in Greenland within the last few years (Boertmann, 1994). The breeding distribution of Greenland white-fronted geese (*Anser albifrons flaviostris*) is limited to West Greenland from the region around Nuup Kangerlua to the Upernavik district (map 30). The entire population winters in the British Isles (Salomonsen, 1990). After a period of decrease in size, the population has increased once again. Since the Greenland white-fronted goose only breeds in Greenland, the country is particularly responsible for its survival. An international conservation plan has been initiated (Stroud, 1992). Canada geese (*Branta canadensis*) occur as two races, a small one and a large one. The latter, which breeds in West Greenland, has expanded and is now more common than the Greenland white-fronted goose in some areas along the west coast (Fox *et al.*, 1996; Bennike, 1990b).

There are 9 duck species in Greenland, some of which are guests and others that breed in the country. The mallard subspecies *Anas platyrhynchos boschas* is endemic to Greenland. It nests by small lakes and protected coasts and winters along the coast in the open water area in West Greenland and by Tassilaq/Ammassalik (Boertmann, 1994). Common eiders (*Somateria mollissima*) have a circumpolar distribution and are common breeding birds along Greenland's coasts, more frequently on the west than the east coast (Salomonsen, 1990). It is estimated that between 10,000 and 100,000 pairs breed in West Greenland (Boertmann *et al.*, 1996). The greatest concentration of breeding common eiders occurs in Avanersuaq and in the Kangaatsiaq fjord network (map 31). The number of breeding birds in West Greenland has decreased in the past century (Salomonsen, 1967; Frimer & Nielsen, 1990). Eiders that breed in West Greenland probably winter in the open water area around South Greenland (Salomonsen, 1967). Important moulting areas for common eiders located along Qeqertarsuaq are shown on map 21. King eiders (*Somateria spectabilis*) breed in the High Arctic. In July/August the males migrate to moulting sites in southern Upernavik and Qeqertarsuup Tunua. A number of females follow later on in August/September, after which the rest of the females and the juveniles arrive. Important moulting areas for king eiders along Qeqertarsuaq are shown on map 20. The majority of moulting birds come from breeding sites in Eastern Canada (Frimer, 1995b). The number of king eiders found by Qeqertarsuaq during the summer and fall has decreased, but it is not known if the population has decreased or if the birds simply have moved to other areas (Frimer, 1993). During the moult the birds cannot fly and are therefore vulnerable to disturbance. Disturbances caused by hunting, sailing and fishing with trawlers around moulting sites in the Qeqertarsuaq region, may be causing the decline in the occurrence of birds (Frimer, 1995b). Like common eiders, king eiders winter in the open water area off of Southwest Greenland (Salomonsen, 1967). Harlequin ducks (*Histrionicus histrionicus*) nest along gushing streams. All individuals occupy the surf zone during the winter, while moulting males and birds that are not breeding occupy this zone during the summer as well (Boertmann, 1994). Long-tailed ducks (*Clangula hyemalis*) breed throughout Greenland and are common birds in many areas. They nest by lakes, protected coasts and small islands in fjords and the archipelago. Males and non-breeding birds moult during the summer in flocks along protected coasts and in fjords. Red-breasted mergansers (*Mergus serrator*) are rather common breeding birds by lakes and shallow-water coasts in West Greenland.

The white-tailed eagle (*Haliaeetus albicilla*) is Greenland's largest bird of prey. It breeds in West Greenland from Qaqortoq to southern Aasiaat (Hansen, 1979; Bennike & Feilberg, 1982).

The population has been in decline, but after its complete protection in 1973 and a number of studies on its living habits, it is no longer threatened (Salomonsen, 1990). In 1990 the population contained approximately 170 pairs (Kampp & Wille, 1990). Internationally the white-tailed eagle is on the list of species that are not vulnerable, but are close to being so (IUCN, 1996). The peregrine falcon (*Falco peregrinus tunderus*) is a common breeding bird in West Greenland up to Qeqertarsuup Tunua and from there, less common northward to southern Qaanaaq. It occurs in small patches in the region by Tasiilaq/Ammassalik (Boertmann, 1994). The peregrine falcon population has been followed for a number of years by Mattox and colleagues (1988) and Falk & Møller (1988). The gyrfalcon (*Falco rusticolus*), which has a circumpolar distribution, breeds in West, North and possibly Southeast Greenland and therefore, has a greater distribution in Greenland than the peregrine falcon. However, it occurs more sparsely than the peregrine falcon. Gyrfalcons occur in two color morphs, gray and white. The gray morphs breed primarily in the Low Arctic while the white morphs are widely distributed (Boertmann, 1994).

Among the raptors, falcons in particular are objects of international trade. All three species mentioned above are completely protected in Greenland, meaning there is a ban on trade in eggs and live or dead individuals. The species are listed in CITES Appendix I (table 14).

Rock ptarmigans (*Lagopus mutus*) are the only gallinaceous birds (Galliformes) represented in Greenland. They are very common breeding and resident birds and are found in more or less all terrestrial habitats. However, they are most frequent in the lush inland (Salomonsen, 1990; Boertmann, 1994). Rock ptarmigan populations experience large fluctuations.

Waders (Charadrii) comprise a large portion of the terrestrial birds and encompass many of the species that breed in Greenland. They dominate the bird fauna in the High Arctic and of the 11 species of waders that regularly breed in Greenland, 9 breed only in the High Arctic region of the country or have their primary distribution there (Meltofte, 1985). Common ringed plovers (*Charadrius hiaticula*), ruddy turnstones (*Arenaria interpres*), red knots (*Calidris canutus*), dunlins (*C. alpina*), sanderlings (*C. alba*) and red phalaropes (*Phalaropus fulicarius*) are the most numerous High Arctic waders (Meltofte, 1985). In West Greenland purple sandpipers (*Calidris maritima*) are breeding birds and many winter near the coast in the open water area. The red-necked phalarope (*Phalaropus lobatus*) breeds primarily in the Low Arctic region of the country by shallow lakes with shore vegetation.

The long-tailed skua (*Stercorarius longicaudus*) is a High Arctic species that breeds in small numbers in Qeqertarsuup Tunua and is common in Northeast Greenland and most of North Greenland where the number of breeding birds is strongly dependent on the lemming population. Long-tailed skuas winter in the southern hemisphere. The parasitic jaeger (*Stercorarius parasiticus*) has a more Low Arctic distribution. It commonly breeds along more or less the entire west coast up to southern Upernavik and on the east coast from the Blosserville Coast to Hochstetter Forland. It also winters in the southern hemisphere. Both the pomarine skua (*Stercorarius pomarinus*) and the great skua (*Stercorarius skua*) are common migrant guests throughout large parts of the country in May/June-October (Boertmann, 1994).

Gulls (Laridae) are represented by eleven species in Greenland. A subspecies of the Iceland gull (*Larus glaucoides glaucoides*) breeds only in Greenland and is thought to number between 20,000 and 100,000 pairs in West Greenland (Boertmann *et al.*, 1996). It occurs in the Low Arctic region of the country (map 32) and is found on the west coast up to Qimusseriarsuaq, although most commonly south of Upernavik and north of Nanortalik, and probably up to Kangerlussuaq on the east coast (Salomonsen, 1990). Black-legged kittiwakes (*Rissa tridactyla*) are the most common gulls in Greenland. The majority of colonies are located in West Greenland, especially by Maniitsoq and in northeastern Qeqertarsuup Tunua and they have a scattered distribution in East Greenland (Boertmann *et al.*, 1996).

**Table 14.** Overview of animals species in Greenland that are included in the Washington Convention (CITES-Convention on Trade in Endangered Species of Wild Fauna and Flora). The subject of the convention is the international trade in threatened species.

CITES/Appendix	Content	Animals in Greenland that are included in CITES*
Appendix I	Includes species that are threatened with extinction. Trade in these species or products derived from them is not allowed or only allowed under extraordinary circumstances.	Fin whale, sperm whale, humpback whale, sei whale, blue whale, bowhead whale
Appendix II	Includes species that are not immediately threatened with extinction. However, they will potentially be threatened with extinction if trade is not closely watched and regulated. Appendix II also includes the so-called "look-alike" species. These are species that resemble other species and therefore can be mistaken for species under CITES control. This assures better trade control.	Narwhal, beluga whale, minke whale  Polar bear, Arctic wolf  Snowy owl
Appendix III	Includes species regulated by member states, who wish to have the cooperation of the other members in regulating trade in these species.	Walrus

\* The table only includes species mentioned in the text.

The Arctic tern (*Sterna paradisaea*), Greenland's only tern, occurs throughout the country by both fresh and salt water, but is mainly concentrated in West Greenland, with just a few colonies in South Greenland (Boertmann *et al.*, 1996). It is estimated that there are 30,000 to 60,000 individuals in West Greenland and that the entire breeding population probably does not contain more than 80,000 individuals (Boertmann, 1994; Boertmann *et al.*, 1996). Since they winter by Antarctica, Arctic terns complete one of the longest migrations known to birds.

The alcids (Alcidae) include six species in Greenland, all of which nest in colonies. The black guillemot (*Cephus grylle*) is the most widely distributed, while Atlantic puffins (*Fratercula arctica*) and razorbills (*Alca torda*) are less common and have a scattered distribution. Thick-billed murres (*Uria lomvia*) nest in 21 colonies in West Greenland, with more than half of the individuals occurring in five colonies in Avanersuaq (map 33). Additionally, there are two colonies on the east coast (Kampp *et al.*, 1994). The total population estimated at 535,000 individuals and contains about 5% of the North Atlantic population (Kampp *et al.*, 1994; Boertmann *et al.*, 1996). An 80-90%, or higher, decrease in population size has occurred in the population from Upernavik to Qeqertarsuup Tunua, while the northernmost colonies in Upernavik and Avanersuaq County, which contain 80% of Greenland's total population, appear to be unchanged (Kampp *et al.*, 1994). Common murres (*Uria aalge*) are found in colonies with thick-billed murres in South Greenland, Paamiut, Nuuk and Maniitsoq (Boertmann *et al.*, 1996).

Little auks (*Alle alle*) breed primarily in the High Arctic and are the most numerous birds in Greenland. Millions of pairs nest in Avanersuaq and by Ittoqqortoormiit. It is estimated that there are 20 million pairs of little auks in Avanersuaq (Boertmann *et al.*, 1996), which accounts for about 80% of the global population (Nettleship & Evans, 1985). In addition, it is estimated that about 3.5 million pairs nest at the entrance to Ittoqqortoormiit (Kampp *et al.*, 1987).

Snowy owls (*Nyctea scandiaca*), the only breeding owls found in Greenland, breed in the High Arctic. The Arctic lemming is the most important prey item for snowy owls and breeding success depends on the number of lemmings. The snowy owl is listed in CITES Appendix II (table 14).

Among the passerines (Passeriformis), the raven (*Corvus corax*) is the country's only corvid. It breeds throughout Greenland, except in the northernmost regions, and winters close to nesting sites. Ravens are often seen in areas close to cities where they feed on trash and other

items. The common redpoll (*Carduelis flammea*) is a primarily Low Arctic species. It is most common in continental areas in willow and birch scrub. Towards the north, it is replaced by the Arctic redpoll (*Carduelis hornemanni*), which is a primarily High Arctic species. In contrast to common redpolls, Arctic redpolls winter in Greenland. The snow bunting (*Plectrophenax nivalis*) is a common breeding bird throughout the country. It nests in areas with large boulders and is also found in inhabited areas. Snow buntings winter in the southernmost parts of the country and further north during mild winters (Boertmann, 1994). Northern wheatears (*Oenanthe oenanthe*) breed primarily in the country's Low Arctic regions in dry, rocky areas. They are the only true insectivorous birds in Greenland. The Lapland bunting (*Calcaeus lapponicus*) breeds primarily in Low Arctic regions of the country and is most often found in lush, continental areas with birch and willow. During mild winters, a small portion of the population winters in southern West Greenland (Boertmann, 1994).

### 3.1.7. Mammal (Mammalia) diversity

The short distance between the Canadian islands and North Greenland means that terrestrial mammals were able to immigrate to the region from Canada after the last ice age and disperse to East Greenland, via Northeast Greenland and West Greenland. The Greenland Ice Cap reaches the coast in some places creating natural barriers to the dispersal and distribution of mammalian species. Vibe (1981b; 1990a) describes Greenland's terrestrial mammals with respect to distribution, diet, reproduction, etc.

There are eight species of wild terrestrial mammals (Mammalia) in Greenland; two small herbivorous species, two large herbivorous species and four carnivorous species. Arctic hares (*Lepus arcticus*), which are distributed throughout Greenland except for the southwest coast, are most numerous in Northeast and South Greenland. They most likely occur as three subspecies that have teeth that are angled further forward the further north they live. The subspecies have possibly developed as a result of an adaptation to cropping the herb-like vegetation of the north (Vibe, 1990a). The Arctic lemming (*Dicrostonyx torquatus groenlandicus* or *D. groenlandicus*), which also is herbivorous, is the only rodent (Rodentia) in Greenland. It is distributed in Northeast Greenland from Washington Land across Peary Land to Cape Dalton on the south coast. Lemmings comprise the staple diet of ermines (*Mustela erminea*), which have the same distribution. The lemming population crashes when it has grown so large that the vegetation is overexploited. This influences population numbers of predators that feed on it.

Arctic foxes (*Alopex lagopus*), which are the only terrestrial mammals with a distribution throughout Greenland, occur as two races. White foxes (*A. l. lagopus*) are found primarily in Northeast Greenland where they feed on lemmings and therefore, experience large population fluctuations. Blue foxes (*A. l. coerulescens*) are associated with the coastal zone, which ensures a stable food supply and hence, a stable population. Just as the white fox continues to immigrate to Greenland from Canada, the Arctic wolf (*Canis lupus*) makes its way from Canada to North and Northeast Greenland. Only a few wolves have been observed and whether they breed in the country is unknown. Arctic wolves are protected throughout Greenland, except by Ittoqqortoormiit. They are listed in CITES Appendix II (table 14) and have been registered as a globally threatened species, but are no longer considered vulnerable (IUCN, 1996). Wolverines (*Gulo gulo*) are occasionally found in Northwest Greenland on incursions from Canada.

One of the large herbivores, the caribou (*Rangifer tarandus*), occurs as two subspecies. Caribou (*R. t. groenlandicus*) are found on the west coast and are most numerous in regions by Nuuk, Maniitsoq and Sisimiut (map 10). As shown on the map, domesticated reindeer (*R. t. tarandus*) have been introduced in some regions. Some of these are feral and have possibly interbred with caribou in some areas. The other subspecies of caribou, the Peary caribou (*R. t. pearyi*), is genetically identical to the now extinct *R. t. eogroenlandicus*, which previously was

distributed in all of North and East Greenland down to Ittoqqortoormiit. Peary caribou are now possibly found in Inglefield Land in Avanersuaq. Peary caribou immigrate to Greenland from Ellesmere Island in Canada.

The other large herbivore, the muskox (*Ovibos moschatus*), occurs naturally in North and East Greenland southward to Ittoqqortoormiit (map 12). The majority of muskoxen are found within the borders of the National Park and are therefore partially protected from hunting. As part of the business development initiative in West Greenland, muskoxen have been translocated from East to West Greenland (map 12).

In the past, attempts have been made to introduce a number of domestic animals. The first domesticated species brought to Greenland is the dog (*Canis familiaris*). It is used to pull sleds on the east coast and on the west coast in the areas north of Sisimiut. There are thought to be about 30,000 sled dogs in Greenland (DFFL, 1994). Sled dogs have retained many of their original instincts and aid hunters during polar bear hunts (Vibe, 1990a). Other dog species are banned to retain the special qualities that sled dogs possess.

The sheep (*Ovis* spp.) is another mammal that has been brought to Greenland in large numbers. There are about 60 sheep farms in South Greenland and one in Nuuk County (map 5). In 1997 there were about 20,000 sheep in the country (Landbrugsrådet, 1997).

## 3.2. *Limnic species diversity*

### 3.2.1. *Algal diversity*

Freshwater algae can be single-celled, colonial or multicellular and filamentous. They are either planktonic or attached to aquatic plants or the bottom substrate (benthic). They are responsible for primary production, along with aquatic plants, in freshwater bodies. Species distribution and amount of primary production depend on physical and chemical factors, as well as latitude.

Information regarding Greenland's freshwater algae is very scarce and the occurrences of most of the groups are still not well known. The most comprehensive general survey is Bachmann (1921). Representatives from 11 classes of algae, with approximately 1,900 species, are known in Greenland (table 15).

Diatoms (Bacillariophyceae) comprise the best-known class of algae. Algae collections from West, East and North Greenland have been investigated and from these, about 1,000 species and their ecology have been documented (Foged, 1953; 1955; 1958; Johansson, 1980). Diatoms are present in many different types of localities: among mosses in springs and watercourses; on moist cliff faces; on rocks in pools of water and watercourses (Kawecka, 1985) and as plankton in ponds and lakes.

Desmids belong to the class Conjugatophyceae. In the Arctic this class has a particular appearance. There are relatively few species, but the genus *Cosmarium* with many species is richly represented. In Greenland, the flora in the south and west is especially well studied and about 400 species are known from these areas (Larsen, 1904; 1907; Bachmann, 1921; Lenzenweger, 1989; Sørensen & Pfeifer, 1992). Filamentous algae of the class Conjugatophyceae, primarily of the genera *Zygnema*, *Spirogyra* and *Mougeotia*, are particularly found near watercourses.

Golden-brown algae (Chrysophyceae and Synurophyceae) form the third-best studied group of algae. Studies are mainly based on collections made in more recent years (see Kristiansen, 1992 for a popular review). 83 species of algae have been recorded in Greenland (Kristiansen,

**Table 15.** Overview of freshwater algae.

Taxonomic group (Classes)	Number of species	Sources
Cyanophyceae (Blue-green algae)	127	Larsen, 1904; 1907; Bachmann, 1921; Böcher, 1950; Pedersen, 1976; Nygaard, 1977; Sørensen & Pfeifer, 1992.
Rhodophyceae (Red algae)	6	Larsen, 1904; 1907; Bachmann, 1921.
Cryptophyceae (Cryptomonads)	3	Bachmann, 1921; Nygaard, 1977; Sørensen & Pfeifer, 1992.
Dinophyceae (Dinoflagellates)	21	Larsen, 1904; 1907; Bachmann, 1921; Nygaard, 1977; Sørensen & Pfeifer, 1992.
Chrysophyceae and Synurophyceae (Golden-brown algae)	83	Nygaard, 1977; Kristiansen, 1994; Ikävalko et al., 1996.
Xanthophyceae (Yellow-green algae)	7	Larsen, 1904; 1907; Bachmann, 1921.
Bacillariophyceae (Diatoms)	1,000*	Foged, 1953; 1955; 1958; Johansson, 1980; Kawecka & Leo, 1985.
Euglenophyceae (Euglenoids)	7	Bachmann, 1921; Sørensen & Pfeifer, 1992.
Chlorophyceae (Green algae)	200*	Larsen, 1904; 1907; Bachmann, 1921; Nygaard, 1977; Sørensen & Pfeifer, 1992.
Conjugatophyceae	400*	Bachmann, 1921; Larsen, 1904; 1907; Lenzenweger, 1989; Sørensen & Pfeifer, 1992.
Charophyceae	5	Langangen et al., 1996.
<b>Total number of species</b>	<b>App. 1,900</b>	Compiled by Jørgen Kristiansen, 1996.

\* These numbers are an estimate of the number of species.

1994; Ikävalko *et al.*, 1996). There are various types of distributions among the golden-brown algae in Greenland dependent upon locality types and latitude, but studies of these have not yet been completed. At the global level, some of the species are cosmopolitan, such as *Synura petersenii*, which is very common everywhere, while others have a wide but very scattered distribution (*e.g.*, *S. mammillosa*). Within the golden-brown alga genus *Mallomonas*, widely different distribution patterns occur among species. *Mallomonas acaroides* is associated with the northern hemisphere's temperate and Arctic regions, while *M. duerrschmidtii* is restricted to North America and Greenland, and *M. variabilis* is only found in Northern Europe and Greenland. The species *M. transsylvanica* has a bipolar distribution and is found both in the Arctic and Sub-Antarctic, while the species *M. nuussuaqensis* is described from the Nuussuaq peninsula in West Greenland and is presumably endemic (Wilken *et al.*, 1994). The golden-brown algae flora is also characterized by a high number of endemic, solitary *Dinobryon* species (Nygaard, 1977). The filamentous golden-brown alga *Hydrurus* is found in watercourses (Johansson, 1980).

Information on the remaining classes of algae is more sporadic. The green algae (Chlorophyceae) comprise about 200 species in Greenland (Larsen, 1904; 1907; Bachmann, 1921; Nygaard, 1977; Sørensen *et al.*, 1992) that occur as plankton in lakes and ponds, filamentous forms in watercourses (Johansson, 1980) and aquatic vegetation in lakes (species of the genera *Cladophora*, *Ulothrix*, *Microspora* and *Oedogonium*). Red pigmented green algae, particularly *Chlamydomonas nivialis*, but also a dozen other species, color glaciers red locally (Kol, 1969; Sørensen & Pfeifer, 1992). Blue-green algae (Cyanophyceae) are represented by 127 species (Larsen, 1904; 1907; Bachmann, 1921; Böcher, 1950; Nygaard, 1977; Pedersen, 1976a; Sørensen & Pfeifer, 1992) that occur in the plankton and as slimy coatings on substrates in moist places. *Nostoc pruniforme* occurs as tomato-sized spheres in lakes. A characteristic flora of blue-green algae is found in hot springs (Pedersen, 1976a).

**Table 16.** Overview of attached marine algae.

Taxonomic group	Number of species	Source
Cyanophyceae (Blue-green algae)	13	Pedersen (1976) – unpubl. rev. 1997
Chrysophyceae (Golden-brown algae)	1	Pedersen (1976) – unpubl. rev. 1997
Dinophyceae (Dinoflagellates)	1	Pedersen (1976) – unpubl. rev. 1997
Xanthophyceae (Yellow-green algae)	3	Pedersen (1976) – unpubl. rev. 1997
Rhodophyceae (Red algae)	52	Pedersen (1976) – unpubl. rev. 1997
Fucophyceae (Brown algae)	83	Pedersen (1976) – unpubl. rev. 1997
Chlorophyceae (Green algae)	53	Pedersen (1976) – unpubl. rev. 1997
Charophyceae	9	Langangen et al., 1996.
<b>Total number of species</b>	<b>215</b>	Compiled by Poul Møller Pedersen.

### 3.2.2. Aquatic plant (*Limnophyte*) diversity

Most of the lakes in Greenland do not have many vascular plants. 31 species of aquatic vascular plants (limnophytes) have been found that grow more or less submerged in fresh water (Fredskild, 1981; 1992). Most species are found in Low Arctic lakes and ponds. The number of aquatic plants present gradually decreases from 25 species in South Greenland to just three species in North Greenland, where Sabine's semaphore grass (*Pleuropogon sabinei*) is the only true High Arctic aquatic plant. Common mare's-tail (*Hippuris vulgaris*) and *Ranunculus confervoides* are found throughout Greenland, although less commonly towards the north. The pondweed genus (*Potamogeton*) is represented by seven species and is the largest of the 15 genera found in Greenland. Aquatic plants are most often sterile in lakes, but flower in the outlet, where the nutrient content is the greatest. Slender pondweed (*Potamogeton filiformis*) and Eurasian water milfoil (*Myriophyllum spicatum*) are characteristic plants in nutrient-rich water. The first mentioned species is also found in some of the saline lakes. Characteristic plants in nutrient-poor water are burreed (*Sparganium hyperboreum*), alternate flowered milfoil (*Myriophyllum alterniflorum*) and spiny spore quillwort (*Isoetes echinospora*). Because of strong currents and coarse bottom substrates, vascular plants cannot attach to the bottom of streams. Where the current is weak however, intermediate water-starwort (*Callitriche hamulata*) and red pondweed (*Potamogeton alpinus*) can be found.

### 3.2.3. Invertebrate diversity

Species composition and the number of species present depend on the region. The greatest number of invertebrate species is found in South Greenland. Some species are distributed throughout the country, while others, such as some crustaceans, arrived in Greenland from northern Canada and have a northwestern distribution. Other species originated from the sea and occur in lakes that at one point were connected to the sea (Røen, 1981).

The meiofauna (animals less than 1 mm), which includes rotifers (Rotifera), tardigrades (Tardigrada) and micrognathozoans (Micrognathozoa), is not well known. The first two aforementioned phyla are known for being able to tolerate large environmental fluctuations and have adapted to diverse environments in polar areas. Radioactive hot springs on Qerqertarsuaq house many rotifers and both tardigrades and rotifers are found on the Greenland Ice Cap (Funch, pers. comm.). In 1994 an unknown animal was found in a cold homeothermic

spring, Issungua Spring, on the eastern part of Qerqertarsuaq. The animal was examined at the Zoological Museum in Copenhagen, Denmark and described as a new species, *Limnognathia maerski*. This new species was placed in a new class, Micrognathozoa, in the group Gnathifera, but there is a continuing discussion as to whether the species should be placed in its own phylum. *L. maerski* has since been found in three other cold homeothermic springs on Qerqertarsuaq. A new species in the class Micrognathozoa was recently discovered in a cold homeothermic spring on an island in the Subantarctic and other than this, there are no other known representatives of the group (R. M. Kristensen, pers. comm.).

Røen (1981) describes Greenland's freshwater fauna. Poorly developed colonies of freshwater fungi (Spongillidae) have been found. They are probably comprised of three different species. Another sedentary group, bryozoans (Bryozoa), is represented by three to four species. Individuals are attached in colonies to rocks, plants and other substrates and filter planktonic algae from the water.

There are two known mollusk (Mollusca) classes in Greenland that live in fresh water. They are the freshwater snails (Gastropoda), which are represented by one pond snail species (*Lymnaea vahl*) and one trumpet, or ram's horn, snail species (*Gyraulus arcticus*), both of which are found in nutrient-rich ponds on the west coast, and the bivalves (Bivalvia), which are represented by *Pisidim steenbuchi*, found in deep water in a few lakes.

Crustaceans (Crustacea) are very well studied (Røen, 1958a; 1958b; 1959; 1962a; 1962b; 1963; 1966; 1968; 1987; 1992; 1994) and with 65 species, of which most of them are entomostracans (Entomostraca), dominate the freshwater fauna. A taxonomic review is given in table 12. They include 29 species of daphnia (Cladocera), of which the species *Rhyncotolona kistarae* and *Alona fabricii*, which are limited to the southernmost part of Greenland, should be considered endemic, and 17 copepod (Copepoda) species. The number of generations of daphnia is lowest furthest north and there is no seasonal variation in terms of size, as is observed in more southerly regions. Flotation devices have probably been reduced, since the cold water is very viscous (Røen, 1981). Only three malacostracan species (Malacostraca) have been found. The malacostracans, which include a mysid species (*Mysis littoralis*), are believed to have marine origins, as are an ostracod (Ostracoda) species and the calanoid species *Limnocalanus macrusus*. They were cut off from the sea when the ground rose during the ice age sealing inlets from the sea and have adapted to the freshwater environment (Holmquist, 1959; Røen, 1962a).

The most dominant insects (Insecta) in fresh water are the larvae of mosquitoes and midges, of which 106 species are midges (Chironomidae). Caddisfly larvae (Order Trichoptera) are represented by eight freshwater species. Of the adult aquatic insects, five beetle species (Coleoptera) have been found in fresh water: one whirligig beetle species (*Gyrinus opacus*), the Arctic beetle (*Hydroporus melanocephalus*) and *Columbetes dolabratus* (Røen, 1981) and two hydrophilid beetle species (Hydrophilidae) (one of them is introduced) (table 13). *Columbetes dolabratus* is Greenland's biggest beetle and can reach sizes of up to 15 mm. In contrast to the Arctic beetle, it cannot tolerate being frozen in and in the fall seeks out larger lakes that do not freeze along the bottom. Additionally, seven species of freshwater mites (Hydrachnidae) have been found (Lettevall, 1962).

A single species of leach (Hirudinea), *Theromyzon garjaewi*, has been found (Røen, 1981). Other parasites on freshwater organisms include flukes (Trematoda), tapeworms (Cestoda), roundworms (Nematoda) and copepods (Copepoda).

The larvae of various insects and worms such as enchytraeids (Oligochaeta) and roundworms (Nematodes) inhabit the benthic zone of freshwater areas.

### 3.2.4. Fish (*Osteichthyes*)

Three fish (*Osteichthyes*) species breed in Greenland's fresh waters. Three-spined sticklebacks (*Gasterosteus aculeatus*) spawn in small lakes and water with moderate currents, while Arctic char (*Salvelinus alpinus*) spawn in lakes and streams in areas protected from currents (Muus, 1990). Kapisillite Stream, located at the base of the fjord Nuup Kangerlus, is the only stream in Greenland where Atlantic salmon (*Salmo salar*) spawn (Muus, 1990). Greenland's fish will be discussed in more detail in section 3.3.4.

## 3.3. Marine species diversity

### 3.3.1. Phytoplankton diversity

Planktonic marine algae (phytoplankton) are found in many shapes and sizes, either as unicellular organisms or in colonies (Hansen & Smidt, 1971). Diatoms are considered the most dominant group of marine phytoplankton during spring blooms, while the other groups typically are dominant after the bloom (see section 2.3.2.). The most comprehensive literature on the diversity of marine phytoplankton around Greenland is Grøntved & Seidenfaden (1938) and Braarud (1935). More recently, studies have been more sporadic, particularly in the region by Qeqertarsuaq, from where studies by Thomsen (1982) can be mentioned. In addition, information can be gathered from field reports prepared on the basis of materials from courses at the Arctic Station on Qeqertarsuaq.

Diatoms (Bacillariophyceae) are observed in the waters surrounding Greenland both on the east and west coast. They comprise a large number of species (app. 250), of which the most dominant are from the genera *Chaetoceros*, *Nitzschia* and *Thalassiosira* (Grøntved & Seidenfaden, 1938; Gillbrich *et al.*, 1991; Weslawski *et al.*, 1991). Diatoms are surrounded by cell walls (frustules) and are either unicellular or colonial. Their most important nutrient substrate is silica (Sakshauge, 1991). In contrast to other phytoplankton groups, diatoms reproduce sexually. Diatoms can be pelagic or benthic and as already mentioned, are dominant during the spring bloom (Andersen, 1989; Smidt, 1979).

Golden-brown algae (Chrysophyceae) occur as either unicellular or colony forming pelagic algae. About 15 species of golden-brown algae can be found in the waters surrounding Greenland (Thomsen, pers. comm.). By Qeqertarsuaq seven species have been observed: *Actinomonas mirabilis* (Kent), *Bicosoeca maris*, *Bicosoeca gracillipes* (James-Clark), *Chryso-sphaerella salina* (Birch-Andersen), *Dinobryon balticum*, *Dinobryon petiolatum* (Willén) and *Paraphysomonas aff. foraminifera* (Lucas) (Thomsen, 1982).

Cryptomonads (Cryptophyceae) consist of unicellular organisms with flagella. About ten marine cryptomonad species can be found in Greenland (Thomsen, pers. comm.). Cryptomonads have been found on both the east and west coast (Weslawski *et al.*, 1991; Smith *et al.*, 1985). Species belonging to the genus *Cryptomonas* have been observed to occur in the Greenland Sea (Weslawski *et al.*, 1991).

Blue-green algae (Cyanophyceae) occur in unicellular or colonial forms and reproduce asexually by cell division. There are approximately ten species of blue-green algae in Greenland (Thomsen, pers. comm.).

Prymnesiophytes (Prymnesiophyceae) and members of the subgroup Coccolithoraceae have been observed by Qeqertarsuaq (Thomsen, 1982), where the groups occur in the nanoplankton. There are approximately 38 species from these groups represented in Greenland, with species of the genus *Chrysochromulina* dominating the prymnesiophytes in the nanoplankton and species of the genus *Pappomonas* dominating the Coccolithoraceae (Thomsen, 1982). The

species *Phaeocystis pouchetii* is believed to occur on both the west and east coast (Grøntved & Seidenfaden, 1938; Gillbrich, 1959; Weslawski *et al.*, 1991).

Pedinophyceae species have been observed on both the west and east coast (Ostenfeld & Paulsen, 1904; Ostenfeld, 1910; Grøntved & Seidenfaden, 1938; Weslawski *et al.*, 1991). The most dominant taxa within the group are *Ceratium* spp., *Dinophysis* spp., *Glenodinium* spp. and *Peridinium* spp. Based on studies by Grøntved & Seidenfaden (1938), it is estimated that there are about 50 Pedinophyceae species in the waters surrounding Greenland.

It has not been possible to estimate species numbers for the remaining groups of algae, which include green algae (Chlorophyceae), euglenoids (Euglenophyceae) and dinoflagellates (Dinophyceae), among others.

### 3.3.2. Attached marine algae diversity

Denmark has long studied attached (benthic) marine algae along Greenland's tremendous coastline. Collections were made already at the beginning of the 1800s, partly in connection with the publication of *Flora Danica*. The first comprehensive survey of Greenland's marine, benthic vegetation was made public in 1893 by L. K. Rosenvinge, who investigated previously collected material and his own collections from along the west coast. This survey was later supplemented by assorted works that also included East and South Greenland (Jónsson, 1904; Lund, 1959; Pedersen, 1976b).

These works are the basis for the species numbers presented here, with later additions taken into account. Studies of algae cultures have allowed researchers to combine various micro- and macroscopic stages and to describe morphological variation under different conditions for some species. This has resulted in changes in the concept of species and in some cases, changes in nomenclature.

According to the revision conducted for the present review, there are 215 species of attached marine algae in the waters surrounding Greenland (table 16). They are distributed across eight classes, but three classes dominate and have the largest number of species; the brown algae (Fucophyceae) comprise 83 species, the red algae (Rhodophyceae) comprise 52 species and the green algae (Chlorophyceae) comprise 53 species (Pedersen, 1976b; rev. 1997). A few species have a very limited occurrence in Greenland. For example, the red algae *Corallina officinalis* and *Polysiphonia fucooides* are only found in the fjord Nuup Kangerlua by Kapisillit. It has been suggested that these species may have been transported to Greenland with the arrival of the Norsemen. They have perhaps found a niche in the area, which was well visited by the Norsemen, where they were able to survive due to the relatively high water temperatures during the summer. Furthermore, juvenile specimens of the brown alga *Leathesia difformis* have been found in a high altitude rock pool in the harbor of Qeqertarsuaq. The species has undoubtedly been brought in on the hull of a ship, but its distribution in Greenland will probably be very limited.

The occurrence of well-developed, benthic marine vegetation is dependent upon a sufficient amount of light, a suitable stable substrate (cliffs, boulders or large rocks), a sufficiently high salt concentration and suitable temperatures. The amount of light and the length of the ice-free period are closely related. The ice-free period can be so short that plants do not have time to build up enough biomass to complete their life cycle. This means that the number of species gradually decreases from south to north. It is especially perennial species that are affected. For example, knotted wrack (*Ascophyllum nodosum*) has its northern boundary in Qeqertarsuaq Tunua. Knotted wrack is characterized by the formation of a bladder at the end of the growing season. By Kronprinsens Ejland, plants with bladders reminiscent of a string of pearls have been found, indicating that only a small amount of biomass is produced over the course of the growing season. Of course, plants with a short generation time, such as

filamentous green algae species of the genera *Ulothrix* and *Urospora*, can easily complete their life cycle in the short amount of time available.

Drifting sea ice has a large effect on vegetation in the littoral zone and in the uppermost part of the sublittoral zone. Wind and currents press ice against the coast and can completely destroy the vegetation. In such localities, the littoral zone is completely devoid of vegetation and, due to the mechanical effects of the ice, vegetation can only grow in cracks and crevices. In localities that are protected from drifting sea ice and from strong wave action, the vegetation is dominated by perennial brown algae. Bladder wrack (*Fucus vesiculosus*) occurs uppermost in the zone and is replaced by knotted wrack (*Ascophyllum nodosum*), which dominates in the central part of the littoral zone. In the lower part of the zone, an islet of *Fucus evanesceus* occurs. In localities exposed to waves but only sporadically affected by drifting ice, the vegetation is dominated by various filamentous green algae (e.g., species of the genera *Urospora* and *Ulothrix*).

The water's salinity greatly affects the vegetation in some of the large fjords of East Greenland (e.g., Kangertitivaq and Kejser Franz Josephs Fjord). Here the spring melt can create a substantial layer of fresh water and the normal vertical distribution of species changes. Sediment is another factor that modifies the vegetation. Some streams add sediment in large quantities, which greatly decreases the clarity of the water and sediment is simultaneously deposited on cliffs, making them unsuitable for algal growth. Something analogous to this occurs in glacier fjords.

### **3.3.3. Invertebrate diversity**

An overview of Greenland's marine invertebrates is given below. This type of overview has not been compiled before and the literature used is therefore very scattered (see the reference list for section 5.3.3.3). Due to the short time frame of this project, a complete list has not been gathered. This means that the correction of synonymous species names, in particular, should be viewed as incomplete and the review should be regarded as preliminary. There are still several marine areas around Greenland that have not been scientifically or systematically studied and it should be expected that the actual number of species is larger than the one given.

The species overview of fauna includes species that reside in the region from the littoral zone to a depth of 500 m and does not include meiofauna (animals smaller than 1 mm) and parasitic species. About 2000 species are included in the review of marine invertebrates (table 17). The database with species names can be found at the Greenland Institute of Natural Resources (Grønlands Naturinstitut).

With about 800 species, crustaceans (Crustacea) comprise the largest group of marine invertebrates. Copepods (Copepoda) and krill (Euphausiacea) include species that are keystone species in Greenland's marine ecosystem. Crustaceans also include the most important commercially exploited species in Greenland, the northern pink shrimp (*Pandalus borealis*), and the snow crab (*Chionoecetes opilio*), which is also fished commercially. Polychaetes (Polychaeta) and mollusks (Mollusca) are among the largest groups with 252 and 283 species, respectively. Many of the species are important prey items for birds, fish and marine mammals.

Sponges (Porifera) make up a relatively small and highly specialized phylum. Around 200 extant species of marine sponges, distributed across two classes, Calcarea and Demospongiae, have been identified in Greenland. Marine sponges are usually sedentary filter feeders. Most sponges have a skeleton composed of calcium or siliceous spicules embedded in the tissue. Food intake and respiration takes place through numerous pores in the surface. Sponges often occur as crust formations or small buds on rocks and cliffs or as epifauna on other organisms.

Cnidarians (Cnidaria) in Greenland comprise about 150 hydrozoan (Hydrozoa) species, 12 scyphozoan (Scyphozoa) species and about twenty coral and sea anemone (Anthozoa) species. Hydroids undergo a polypoid stage, a medusa stage or both. Athecate and thecate hydroids undergo two stages in their life cycle, a sedentary polypoid stage and a free-swimming, sexually reproductive medusa stage (Anthomedusae and Leptomedusae, respectively). Because of the two stages, classification of these organisms becomes very complicated. The groups Trachymedusae, Narcomedusae and Siphonophora have a very reduced polypoid stage. Among the scyphozoans, the medusa stage is dominant and the polyp stage is limited to a short larval phase. Sea anemones and corals however, have a completely reduced medusa stage. Hydroids fall prey to a number of species including snails, echinoderms and sea spiders. Some sea spiders feed exclusively on hydroids. Pelagic medusas are prey to lump fish and other organisms.

Sipunculans (Sipuncula) and echiurans (Echiura), which resemble sipunculans but are a separate phylum, are represented by respectively, five and one species in Greenland. These two worm-like phyla are sediment feeders that live buried in mud and sand or hidden in boulders and empty shells. Echiurans differ from sipunculans in that, unlike that of the sipunculans, their large proboscis cannot be retracted.

There are 283 mollusk species in Greenland, represented by four aplacophorans (Caudofoveata and Solenogastres), six chitons (Polyplacophora), six scaphopods (Scaphopoda), 173 snails (Gastropoda), 78 bivalves (Bivalvia) and 16 cephalopods (Cephalopoda). Iceland scallop (*Chlamys islandica* Müller), which is harvested for consumption in West Greenland, is a particularly important benthic species (map 45). It is the northernmost scallop species that is of commercial value. The largest Greenlandic populations are found south of Nuuk. The population of Iceland scallops in West Greenland is composed of old, slow growing scallops with a very low recruitment rate. Iceland scallops do not reach sexual maturity until they are over three years of age. The species cannot become established in East Greenland because of the cold, southerly Arctic current, but is found in the inner part of Kong Oscars Fjord and the southernmost part of the Kong Frederik VI Coast (Pedersen, 1994).

Although they are superb for eating and exploited at the local level, blue mussels (*Mytilus edulis* Linné) are not economically important in Greenland. Blue mussels live in abundant numbers in regions where the warm Atlantic Current reaches the coast. In the fjords' pelagic waters, mussel larvae are the most numerous meroplankton group (Smidt, 1979). The pelagic zone also contains large numbers of pteropods: two shell bearing pteropod (Thecosomata) species and one naked pteropod (Gymnosomata) species. Together with other pelagic invertebrates, they are an important food resource for herring and large marine mammals, such as humpbacked whales and bowhead whales.

Among the cephalopods, the squid *Gonatus fabricii* (Lichenstein), which belongs to the order Teuthoidea, is very abundant in the waters surrounding Greenland. It is caught secondarily during shrimp trawls.

Many of the mollusks are of direct interest since many are important prey species for commercially and locally exploited birds, fish and marine mammals. Snails and bivalves are the primary food source for eiders and king eiders. The king eider's principal food sources are the bivalves *Mya truncata* (Linné), *Serripes groenlandicus* (Bruguière) and *Ciliatocardium ciliatum* (Fabricus) (Frimer, 1993). Walrus feed primarily on bivalves of the genera *Serripes*, *Cardium*, *Mya*, *Hiatella* and *Astarte*, while bottlenose dolphins, sperm whales, killer whales, long-finned pilot whales and narwhals to a large degree feed on cephalopods (Vibe, 1990a).

Polychaetes (Polychaeta), which belong to the annelid phylum (Annelida), are a widely distributed group of marine invertebrates represented by 252 species in Greenland. The majority of Greenlandic polychaetes are benthic and live partly as epifauna and partly as infauna

**Table 17.** Overview of marine invertebrates. The overview encompasses about 2,000 species from the littoral zone to a depth of 500 m and does not include meiofauna and parasites. Correction for synonymous names is not complete and many marine areas have not yet been investigated, the overview should therefore be regarded as incomplete.

Taxonomic group	Taxonomic group	Taxonomic group	Number of species
Sponges (Porifera)			app. 200
Cnidaria			177
Scyphozoa			12
Hydroids and medusas (Hydrozoa)			145
	Athecate		27
	Anthomedusae		15
	Thecate		79
	Leptomedusae		9
	Trachymedusae		5
	Nacromedusae		2
	Siphonophora		8
Sea anemones and corals (Anthozoa)			app. 20
Sipuncula			5
Echiura			1
Mollusca			283
Aplacophora			4
	Caudofoveata		2
	Solenogastres		2
Chitons (Polyplacophora)			6
Scaphopoda			6
Snails (Gastropoda)			173
Bivalvia			78
Cephalopoda			16
Annelida			252
Polychaeta			252
Crustacea			805
Entomostraca			204
	Ostracoda		54
	Copepoda		150
Thecostraca			14
	Ascothoracida		1
	Barnacles (Cirripedia)		13
Malacostraca			587
	Pyllocarida		1
		Leptostraca	1

*Table 17. (continued)*

Taxonomic group	Taxonomic group	Taxonomic group	Number of species
	Eucarida		38
		Krill (Euphausiacea)	6
		Decapoda	32
	Peracardia		548
		Mysidacea	22
		Cumacea	39
		Tanaidacea	23
		Isopoda	88
		Amphipoda	376
Sea spiders (Pycnogonida)			25
Bryozoa			241
Cyclostomata			33
Ctenostomata			12
Cheilostomata			196
Entoprocta			5
Nemertea			7
Chaetognatha			4
Priapulida			2
Ctenophora			4
Brachiopoda			7
Echinodermata			112
Sea lilies (Crinoidea)			7
Starfish (Asteroidea)			40
Brittle stars (Ophiuroidea)			38
Echinoidea			9
Sea cucumber (Holothuroidea)			18
Tunicata			55
Sea squirts (Ascidiacea)			50
Salps (Thaliacea)			2
Larvacea			3
<b>Total number of species</b>			<b>app. 2,000</b>

in the sediment. The blow lugworm (*Arenicola marina* (Linné)) lives in the sediment and is particularly common on the west coast. Some sedentary species (including individuals of the family Serpulidae) construct protective tubes that they can retreat into. According to Smidt (1979), polychaetes are very important for the composition of the meroplankton, where they dominate among the larvae of benthic organisms. There are two planktonic polychaetes of the genus *Tomopteris* and two of the genus *Myzostoma* that are parasites on feather stars (genus *Antedon*). Polychaetes are a minor part of the diet of Greenland cod and narwhals.

Annelids (Annelida) also include the class Oligochaeta, of which the aquatic species are very small and difficult to identify. They are usually found in rich muddy bottoms in estuaries or under up-washed algae. Also among the annelids are the leeches (Hirudinea), which only comprise a few marine species and primarily live as parasites on fish and skates. These groups are not included in the species overview.

Crustaceans (Crustacea) belong to the arthropod phylum (Arthropoda). They are the most species-rich marine group in Greenland with about 800 species represented by 54 ostracods (Ostracoda), 150 free-living and parasitic copepods (Copepoda), fourteen species of Thecost-raca (Ascothoracida and Cirripedia (barnacles)) and over 500 malacostracans (Malacostraca). Malacostraca is thereby the largest class and is represented by 376 amphipods (Amphipoda), 32 decapods (Decapoda), 22 mysidaceans (Mysidacea), 39 cumaceans (Cumacea), 23 tanaidaceans (Tanaidacea) and 88 isopods (Isopoda).

Among the crustaceans, shrimp are of the largest commercial interest. The pink shrimp (*Pandalus borealis* (Krøyer)) is the most important species in West Greenland's fishing industry (map 43). Pink shrimp have an Arctic-boreal distribution and are found along both the west and east coast of Greenland. Their distribution is determined by salinity, temperature and the composition of the sea bottom. Pink shrimp have been observed at depths ranging from 20 to 900 m, but are usually found at depths of 100 to 600 m. They grow slower, but larger, at lower temperatures, while they grow faster, but smaller, in warmer water. Pink shrimp are one of the most important food sources for Atlantic cod.

Snow crabs (*Chionoecetes opilio* (O. Fabricius)) are found on Greenland's west coast southward to Nunap Isua. Their meat is very tasty and they are commercially exploited (map 44).

Pelagic crustaceans occur in large swarms in North Atlantic regions. Among these are krill (Euphausiacea), which are represented by six species in the waters surrounding Greenland. Krill have light-emitting organs (photophores) by their eyes and legs. They are important in the diet of juvenile Atlantic cod and other juvenile fish, as well as marine birds, seals and whales. Blue whales in particular eat large quantities of krill. Krill feed primarily on copepods and fish fry.

In addition to krill, copepods (Copepoda), mysidaceans (Mysidacea) and amphipods (Amphipoda) are an important part of the plankton. Copepods of the genus *Calanus* are especially important since they form the principal diet of many of the fish and whale species that are commercially exploited. There are three *Calanus* species in Greenland, all of which are herbivorous: *Calanus finmarchicus* (Gunnerus), *C. glacialis* (Jaschnov) and *C. hyperboreus* (Krøyer). One of the most common amphipods is the detritus feeder *Gammarus locusta* (Linné), which lives along the coasts with *laera albifrons* (Leach). These two species play a key role in the diet of other animals including mallards and dunlins (Jensen, 1928). Many amphipods are parasitic or live commensally with other invertebrates and fish. This is true for the orders Poecilostomatoida, Cyclopoida and Siphonostomatoida.

Like the polychaetes, larvae from benthic crustaceans play a key role in the microplankton. Nauplius larvae of barnacles (*Balanus* sp.) are especially dominant (Smidt, 1979).

Crustaceans are an important food source for many marine organisms. Benthic crustaceans, especially decapods (Decapoda), are an important part of the diet of large fish and marine birds, as well as some of the big mammals. Shrimp, crabs and amphipods are important in the diet of Greenland cod, depending upon the size of the individual fish (Nielsen & Andersen, 1993).

Bryozoans (Bryozoa) are composed largely of marine species. There are more than 200 species (the preliminary estimate is 241 species) in Greenland, but despite this large number, not much is known about their actual ecological role in the waters surrounding Greenland. Bryozoans are usually colonial epifauna on other marine invertebrates, shells or rocks and algae. Small bryozoan individuals are easily mistaken for hydroids or algae. Bryozoans eat particulate matter suspended in the water caught with a ciliated tentacle (lophophore). They are consumed by benthic invertebrates, such as snails, which scrape the colonies from the substrate.

Five entoproctans (Entoprocta) are known from Greenland.

Nemerteans (Nemertea) are a phylum of worm-like animals that can reach lengths of several meters. There are probably more than ten species in Greenland. Most are benthic marine animals that live in shallow water between shells and rocks or buried in the sand and mud. Nemerteans primarily feed on polychaetes and crustaceans.

Chaetognaths (Chaetognatha), with their large collective biomass, are very important in the plankton on both the east and west coast of Greenland (Kramp, 1939). In spite of the very large biomass, there are only four species in the waters surrounding Greenland, occurring at depths of over 500 m. *Sagitta elegans* (Verrill) is the most abundant species in the upper, colder water, while *S. maxima* (Conant) is abundant in the deeper, warmer water layer.

The nematode (Nematoda) phylum is not treated in detail in this review. This is because the taxonomy of this group is not very well known. Nematodes are usually very small individuals and form a very species-rich group. They occur in large quantities in the sediment. Food niches are very diverse; some are carnivorous, some feed on plants, some are associated with microfauna and some are sediment feeders. They play an important role in sediment decomposition and can be important food items for the infauna. A parasitic nematode species, *Trichinella spiralis*, is common among sled dogs and polar bears, and slightly less common among Arctic foxes, walruses, seals and whales (Madsen, 1961). Humans can become infected with the parasite if they consume insufficiently cooked or frozen meat of one of these animals.

Priapulids (Priapulida) are represented by the species *Priapulus caudatus* (Lamarck) and *P. bicaudatus* (Danielssen). Both species, which belong to the family Priapulidae, live at depths less than 500 m. Priapulids are soft substrate organisms that live buried in sand and mud, where they reach lengths of up to 20 cm. There are only 15 extant priapulid species in the world and only one family in cold marine water. Priapulids are predatory and feed on soft, slow invertebrates, with polychaetes as an especially important prey item.

Ctenophores (Ctenophora) are abundant in the waters surrounding Greenland, even though there are only four species. One of these is the Arctic *Mertensia ovum* (Fabricius) belonging to the class Tentaculata. The species is a predatory plankton feeder that probably influences plankton composition (Sakshaug *et al.*, 1994). It can reach a diameter of up to eight centimeters with one meter long tentacles. The species can tolerate long periods of starvation by depleting its fat reserves, which explains the large number of jellyfish observed in the winter. *Beroë cucumis* (Fabricius), which belongs to the class Nuda, is the most common species in relatively warm Atlantic water. It lacks tentacles and can reach lengths of up to 15 centim-

eters. The species feeds on other ctenophores, especially *Mertensia ovum* (Fabricius), with which it therefore has an inverse occurrence relationship. Ctenophores occurs in the diet of, for example, Atlantic cod and lumpfish.

The brachiopods (Brachiopoda) are represented by seven species, all of which are found along both the east and west coast. Brachiopods are shell-bearing organisms that, even though they have a very different physiology, superficially resemble bivalves. They have a lophophore, which is used to filter food particles and phytoplankton from the seawater. Most brachiopods live beyond the 200 m depth boundary and are usually fastened with a pedicle to a hard substrate.

There are about 112 echinoderm (Echinodermata) species in Greenland, represented by seven sea lily (Crinoidea) species, 40 starfish (Asteroidea) species, 38 brittle star (Ophiuroidea) species, nine echinoid (Echinoidea) species and 18 sea cucumber (Holothuroidea) species. Echinoderms are exclusively benthic marine animals that superficially appear very different among the various classes. Characteristic for all of the classes however, are their radial symmetry, a skeleton made of calcium ossicles and tube feet.

Sea lilies are partly sedentary, stalked individuals that briefly are able to move about and swim.

Starfish have varying life forms. The polar sea star (*Leptasterias polaris* (Müller & Truchel)), which is very common in Greenland, and sun star species of the genera *Solaster* and *Crossaster*, for example, are predacious and are able to feed on individuals larger than themselves. Sun stars eat organisms such as other echinoderms and bivalves, while other starfish, such as *Pteraster militaris* (Müller), live exclusively as sediment feeders.

The echinoid *Strongylocentrotus droebachiensis* (Müller) is a widely distributed species that when in a group, can control marine algae beds by grazing them very effectively. Echinoids also eat hydroids and other relatively immobile invertebrates. Furthermore, some echinoids live as infauna in the sediment. There is an increasing interest in the possibility of commercially exploiting echinoids in Greenland.

Sea cucumbers live partly as infauna and partly as epifauna. One species, the large, brownish-black *Cucumaria frondosa* (Gunnerus) is a very common epifaunal species in Greenland, found along both the east and west coast. Most sea cucumbers however, live buried in the sediment. This is true for species such as *Chiridota laevis* (Fabricius) and *Myriotrochus rinkii* (Steenstrup).

Echinoderms occur particularly in the diet of sanddabs, Atlantic catfish and bearded seals. Atlantic cod and walrus will occasionally feed on sea cucumbers.

Three tunicate (Tunicata) classes, which together comprise 55 species, have been recorded in Greenland. Sea squirts (Ascidiacea), which are sedentary in their adult life, represent 50 of these species. They are immobile filter feeders that are very common on hard substrates and comprise part of the walrus diet. The remaining five tunicate species are pelagic and include two salps (Thaliacea) and three larvaceans (Larvacea). Tunicates belong to the phylum Chordata and have a ventrally located heart, a dorsal nervous system and a notochord, which in sea squirts is only present during the larval stage. In the salps, the notochord is completely absent, while in larvaceans it is present throughout the life cycle.

### **3.3.4. Fish (Pisces) diversity**

The marine fish (Pisces) are divided into three classes: the cyclostomes (Cyclostomata), which include lampreys and hagfish, the cartilaginous fishes (Chondrichthyes), which include

sharks, skates, rays and chimaeras and the bony fishes (Osteichthyes). The bony fishes are by far the most species-rich class and comprise about 21,000 of the approximately 21,700 fish species known on Earth (Nelson, 1984).

The description of Greenland's fish started about 200 years ago and most of the species have probably been identified. Muus (1990) provides an overview of about 125 species and discusses their distribution. The field guide to Greenland's fish mentions 216 species, of which approximately 150 species are observed regularly, the rest are known only from a few specimens or occur as guests (Nielsen & Bertelsen, 1992). Greenland's fish fauna is also described by Hansen and colleagues (1981). Fish studies have primarily concentrated on commercially important species. In recent years, trawling studies have led to a survey of 164 fish species, including several species of deep-sea fish that otherwise are only poorly known (Okamura *et al.*, 1995).

The species can be divided into two main groups, boreal species that are associated with temperate water bodies, such as the one the Gulf Stream and Irminger Current send up along the coast of Southwest Greenland, and Arctic species that are most abundant north of the submerged ridge in the Davis Strait and in the waters of North and East Greenland (map 2). Boreal species comprise about 40% of the species, as do Arctic species. The rest of the species have a boreal-Arctic distribution. However, many of the species' distributions are not fully known. Species composition and distribution change with climate and Arctic species disperse southward in cold periods, while boreal species become more abundant in milder periods. Examples of boreal species are herring, Atlantic cod and Atlantic halibut, as well as haddock and European plaice, which are guests during mild climate conditions. Typical Arctic species are polar cod, Atlantic spiny lumpsuckers and many of the eelpouts. Included in the boreal-Arctic species are Greenland shark, shorthorn sculpin, Arctic char and sanddabs (Muus, 1990).

Work by Nielsen & Bertelsen (1992) is the basis for the present evaluation of fish species in the waters surrounding Greenland. Species that do not occur regularly or are only represented by a few specimens are not included. Of the around 250 species of fish, the bony fishes dominate with approximately 140 species. The families that contain the most species are the cod (Gadidae), sculpin (Cottidae) and eelpout (Zoarcidae) families. Capelins (*Mallotus villosus*) and sand lances (*Ammodytes* sp.) are abundant and prey items for a number of other fish species, birds and mammals. Of all the fish, the Greenland halibut (*Reinhardtius hippoglossoides*) has the greatest commercial interest. The Atlantic cod (*Gadus morhua*) used to be the species with the greatest commercial interest.

Cyclostomes (Cyclostomata) are represented by hagfish (*Myxine glutinosa*), which are carrion feeders along Southwest Greenland.

The cartilaginous fishes (Chondrichthyes) are generally benthic and are comprised of three shark (Galeoidea) species and four skate (Batoidea) species. The Greenland shark (*Somnios microcephalus*) is the most widely distributed shark. It is found along all the coasts, except for the northernmost ones. In North Greenland it is fished locally and the meat is dried for dog food. Before 1965 it was fished commercially. Experimental fisheries are operated in South Greenland to research the possibility of once again exploiting the species commercially. Skates are found at water temperatures above 0°C. Arctic skates (*Raja hyperborea*) and thorny skates (*R. radiata*) are the only species that occur as far north as Baffin Bay.

In deep water a number of fish species have light-emitting organs on their bodies. There are various species of deep-sea fish from different families. They live at depths ranging from 500-2000 m and information about them is limited. Many species have been observed only because specimens have washed ashore. The females have a light-emitting organ on a spe-

cialized dorsal spine, which functions as bait to lure prey animals in front of the fish's mouth. Males occur as dwarf morphs that, in some species, parasitize the female by attaching to her and forming a common circulatory system (Muus, 1990). Deep-sea fish include the blunt-snout smooth-head (*Xenodermichthys copei*), which is the most common of the six slickhead (Alepocephalidae) species, and the bighead searsid (*Holtbyrnia anomala*), which is the most frequently occurring of the six tubeshoulder (Plathyroctidae) species. The order Stomiatoidei comprises nine species from three different families of deep-sea fish. There are also a couple of ridgehead (Melamphaidae) species.

Herring (*Clupea harengus*) belong to the family Clupeidae. They have been observed as far north as Upernavik on the west coast and Ittoqqortoormiit on the east coast. Herring, which are surface and schooling fish, are boreal and associated with areas with warm Atlantic water. They occur as both migratory and stationary populations within their distribution (Muus, 1990). In fjord regions along the southernmost part of the west coast, herring are observed regularly in spawning condition, but it is not known if fry are produced every year. Herring are exploited locally in Southwest Greenland and further north, they are caught sporadically in gill- and pound nets.

Three-spined sticklebacks (*Gasterosteus aculeatus*) are among the few species that occur in fresh, brackish and salt water. They are found in coastal algal vegetation and in streams and lakes northward to Upernavik and Ittoqqortoormiit. They spawn in fresh water and are found as migrating coastal populations or stationary populations in streams and lakes.

Four families containing seven species, each in its own genus, represent the salmonid fishes. Species belonging to the salmon family (Salmonidae) migrate to the sea, where they are pelagic, and spawn in fresh water. From August to about November, Atlantic salmon (*Salmo salar*) migrate from the American and European continents to forage along Greenland's coasts. Their distribution varies quite a bit from year to year, depending upon the marine surface water temperature, but the northern boundary normally occurs around Aasiaat on the west coast and Ittoqqortoormiit on the east coast. There is only one stream in Greenland where the spawning environment is suitable for Atlantic salmon. It is located at the bottom of the fjord network by Nuuk (Kapisillit) and only produces a small amount of salmon. There have been observations of salmon entering other streams and possibly trying to spawn, but fry have not been observed in any of these. In Greenland, Atlantic salmon are fished both locally and commercially.

The Arctic char (*Salvelinus alpinus*) has the northernmost distribution of the freshwater fishes. It is found in streams and lakes throughout Greenland and along the coasts. It spends its first three years in fresh water, after which it conducts a yearly foraging migration to the sea during the summer months. Migrating Arctic char stay near coastal areas close to the streams where they matured. In the fall, they migrate back to the streams where they hatched. Since the various local populations barely mix, the within-species genetic diversity is probably high. There are also stationary populations that are able to migrate, but remain in fresh water throughout their life. Among these, several types with different life strategies have been observed; a small, dark benthic type that lives close to the shore, a light type that lives in open water and primarily feeds on zooplankton and a larger type that is cannibalistic (Riget *et al.*, 1986). All Arctic char spend the winter in lakes and calm pools in streams. Arctic char are exploited locally in large quantities.

Capelins (*Mallotus villosus*) occur in the region from around Upernavik and southward along the west coast, to north of Tasiilaq/Ammassalik along the east coast, but can be observed further north when the climate is mild (map 34). In coastal and fjord areas, local populations occur that stay close to their place of origin. Part of a large population originating from Iceland occurs in the open sea off East Greenland. This population is on a foraging migra-

tion and aside from occurring between Iceland and Greenland, can be found as far north as Jan Mayen. Capelins are pelagic, schooling fish and are an important link in the food chain between the sea's small organisms and larger fish and marine mammals. Capelins are caught locally when large spawning schools move into shallow water in the spring. They are used for consumption and when dried, as food for sled dogs.

The Arctic telescope (*Protomyctophum arcticum*) and glacier lanternfish (*Benthoosema glaciale*) are the two most common lanternfish (Myctophidae) in the North Atlantic (Muus, 1990). They live and spawn by Greenland, while six additional species are guest species in Greenland. Lancetfishes (Alepisauridae) and barracudinas (Paralepididae) are related families that also are pelagic and move to the surface at night.

The grenadier family (Macrouridae) is common in Atlantic water in the southern part of the Davis Strait. It is one of the most species-rich families. Ten species have been recorded by West Greenland, of which the roundnose grenadier (*Coryphaenoides rupestris*), Günther's grenadier (*C. güentheri*) and onion-eye grenadier (*Macrourus berglax*) are the most common (Jørgensen, 1996).

The cod family (Gadidae) comprises twelve species that are frequently found by Greenland and five species that have been caught only a few times. Cod stay close to the coast and are pelagic or benthic. Atlantic cod (*Gadus morhua*) occur from Qeqertarsuup Tunua southward to Nunap Isua on the west coast and on the east coast northward to Tasiilaq/Ammassalik. In the past, Atlantic cod bred on banks in open water by Southeast and Southwest Greenland. Today, only a few populations are found in the fjords. Occasionally the Irminger Current carries cod larvae from Iceland to Greenland (see map 2). These larvae mature in the waters surrounding Greenland and migrate to Iceland when they reach spawning condition. Only a few migrate back to Greenland. The large fluctuations in Greenland's Atlantic cod populations are partly due to the fact that they are at their northernmost boundary and therefore sensitive to climatic changes. The situation today resembles the one prior to 1920, when Atlantic cod were rare and occurred only sporadically in Greenland. Atlantic cod are exploited locally and commercially.

Another species of cod is the uvak, or Greenland cod, (*Gadus ogac*). It is found close to the coast and in fjords along the west coast from Nunap Isua northward to Upernavik. Polar cod (*Boreogadus saida*) and Arctic cod (*Arctogadus glacialis*) usually live in association with ice. Polar cod are found everywhere along Greenland's coasts and throughout the Arctic, while Arctic cod have a High Arctic distribution (map 35). Polar cod are an important prey species in High Arctic, marine ecosystems associated with sea ice.

Two very similar sand lance (Ammodytidae) species are abundant from South Greenland northward to Ummannaq. They live on fish banks and in shallow water and together with the capelin, are important prey species for predators such as Atlantic cod and salmon.

Three species of catfish, also termed woffish, (Anarhichadidae) have been recorded in Greenland. They are benthic and occur from Nunap Isua northward to respectively, Upernavik and Tasiilaq/Ammassalik on the west and east coasts. Both spotted catfish (*Anarhichas minor*) and Atlantic catfish (*A. lupus*) are caught secondarily by other fisheries (Anon., 1997b). Both species have decreased in abundance in recent years and the populations are estimated to be very small (Anon., 1997b).

Eelpouts (Zoarcidae) are distributed in the northern hemisphere, where they are the most common benthic animals. The eelpout family is among the most species-rich fish families around Greenland. The systematic categorization of species in the genus *Lycodes* is rather unsure, but there are about 18 species, of which some have only been found a few times (Møller, 1996).

Four species of rockfish (Scorpaenidae), all in the same genus, are the only bony fishes in Greenland that bear live young. In the past, ocean perch (*Sebastes marinus*) and deepwater redfish (*S. mentella*) were not regarded as two separate species. They occur in West Greenland in the deep fjords, in the Davis Strait, northward to Uummannaq and in East Greenland from Nunap Isua to Tasiilaq/Ammassalik. Ocean perch are benthic, while deepwater redfish have both benthic and pelagic types. Norway redfish (*Sebastes viviparus*) and Acadian redfish (*S. fasciatus*) have a scattered occurrence by South and Southeast Greenland, respectively. The most important Greenlandic spawning areas for rockfish are located southeast of Greenland and in the southern part of the Denmark Strait and Irminger Basin (Muus, 1990). Larvae are carried by currents from spawning areas southeast of Greenland to West Greenland, where they are found in the southern Davis Strait west of the banks and northward to the banks Lille Hellefiskebanke. Rockfish are fished on the east coast and in West Greenland and a number of juveniles are caught secondarily in shrimp trawls (Engelstoft, 1996).

Eighteen scorpionfish species belonging to three families occur in Greenland: sculpins (Cottidae); flathead sculpins (Psychrolutidae) and poachers (Agonidae). Sculpins live in northern, cool waters. They are associated with the bottom and are found in shallow water. Each species has a different distribution. There are examples of distributions in the High Arctic, in southern West and East Greenland and in central East Greenland. The shorthorn sculpin (*Myoxocephalus scorpius*) is very common along all of Greenland's coasts, except in the northernmost regions where it only occurs in protected areas. It is fished at the local level.

Some of the most common species belong to the lumpfish (Cyclopteridae) and snailfish (Liparidae), which comprise four and ten species, respectively. They attach themselves to rocks or algae with their ventral fin, which has been converted into a suction cup. Lumpfish (*Cyclopterus lumpus*) are found on the west coast northward to Uummannaq and on the east coast northward to Tasiilaq/Ammassalik. They are caught during the summer when they move to coastal areas to spawn between rocks and seaweed. Humans consume the females' roe and the males' meat.

There are five species of flatfish, all belonging to the family Pleuronectidae. Greenland halibuts (*Reinhardtius hippoglossoides*) occur along the entire west coast, including the fjords, up to Smith Sound and along the east coast northward to Ittoqqortoormiit (map 36). They spawn in the Davis Strait south of the submerged ridge and in the eastern part of the Denmark Strait. The banks southwest and west of Qeqertarsuaq are recognized as important maturing grounds for Greenland halibut fry. There are also maturing grounds off the east coast south of Ittoqqortoormiit that stretch southward around Nunap Isua (map 37). Atlantic halibuts (*Hippoglossus hippoglossus*) are the largest of the flatfish. They reach lengths of up to 2.5 m and can weigh several hundred kilos. Sanddabs (*Hippoglossoides platessoides*) are common on the west coast in fjords and in the Davis Strait, from Nunap Isua to Upernavik, and less common along the east coast. The European plaice (*Pleuronectes platessa*) only occurs by South Greenland during mild climate periods (Muus, 1990). The Greenland halibut is exploited both locally and commercially and of all the fish species, has the greatest economic importance to Greenland (map 41 and 42). The rest of the flatfish are only exploited locally and caught secondarily when fishing for other species.

### **3.3.5. Mammal (Mammalia) diversity**

Twenty-two marine mammal species occur in the waters surrounding Greenland, either as breeders or as guests. The seals found here do not occur in the southern seas, while some of the whales are found in both the southern and northern seas (Vibe, 1990a)

Greenland's marine mammals are described by Vibe (1981c; 1990a), who discusses their external morphology, reproduction, distribution, food choice, etc.

The polar bear's (*Ursus maritimus*) distribution is largely determined by the distribution of pack ice. It occurs regularly along the entire east coast of Greenland and in Northwest Greenland. The occurrence of polar bears in Southwest Greenland varies, since it depends on the degree to which they follow the pack ice from East Greenland. Polar bears are rare along the coasts in the open water area between Paamiut and Nuuk, where pack ice normally does not occur, and by Greenland's northernmost coasts along the Arctic Ocean (Born, 1995). Female bears give birth during the winter in so-called breeding dens, which usually are near the coast. Important areas for polar bear breeding dens are marked on map 38. Polar bears are listed in CITES Appendix II (table 14).

The Atlantic walrus (*Odobenus rosmarus rosmarus*) winters in Greenland in two bank regions off central West Greenland (Born *et al.*, 1994) and in Northwest Greenland, where it occurs along banks and in the North Water polynya (map 22). By East Greenland, walruses occur north of approximately 63° N, but with a principal distribution north of approximately 73° N. In East Greenland walruses winter in open water areas along the coast (Born *et al.*, 1995; 1997). The walrus's diet consists mainly of bivalves, which are taken from banks at depths of less than 80 m. Walruses gather close to foraging areas on ice floes or sometimes on land on so-called haul-outs (Born *et al.*, 1995). In contrast to the beginning of the 20th century when several haul-outs were located on both the east and the west coast, today only two haul-outs are known in East Greenland (map 22) (Born *et al.*, 1994). Their narrow food niche and limited distribution make walruses vulnerable to environmental changes and easy targets for hunters (Born *et al.*, 1995). As a consequence, the number of walruses in central West Greenland has decreased sharply since the turn of the century (Born *et al.*, 1994; 1995). Walruses are listed in CITES Appendix III (table 14).

The five true seal (Phocidae) species found in the waters surrounding Greenland are distributed among three genera. Harbor seals (*Phoca vitulina*) occur along the entire west coast, particularly along the southern part, and in Southeast Greenland up to Ittoqqortoormiit. The species has never been as abundant as the other Greenlandic seals (Teilmann & Dietz, 1993). It stays in areas near the coast and is Greenland's only seal that sheds and breeds on land. This makes it very vulnerable to disturbance. The status of the population is unknown. It has probably been declining since the beginning of the 20th century and has disappeared from nine out of 23 known breeding grounds (Teilmann & Dietz, 1993) and decreased at others. Ringed seals (*Phoca hispida*) and bearded seals (*Erignathus barbatus*), both of which are associated with sea ice, occur along all of Greenland's coasts. Among the seals, ringed seals are the most important game species. The bearded seal's tough skin has traditionally been used to make straps and kamik soles. The harp seal (*Phoca groenlandica*) is also an important game species. Harp seals and hooded seals (*Cystophora cristata*) are among the migrant seals. They breed on pack ice both west and east of Greenland and after the breeding season, migrate north along Greenland's west and east coasts.

Whales (Cetacea) are represented by fifteen species in Greenland; nine toothed whales and six baleen whales.

Male sperm whales (*Physeter macrocephalus*) occur in small numbers by West Greenland and a bit more abundantly by East Greenland. Females and their young occur further south in the North Atlantic (Born *et al.*, 1998). In West Greenland, humpbacked whales (*Megaptera novaengliae*) are principally found between Paamiut and Sisimiut, but a few individuals are also observed by the east coast (Born *et al.*, 1998). Bowhead whales (*Balaena mysticetus*) were protected internationally in 1934 after experiencing severe hunting pressure for several hundred years. Just a few hundred individuals on the west coast around Sisimiut and Qeqertarsuaq are found in late winter and early spring. A few individuals have also been observed along the northeast coast during the summer (Born *et al.*, 1998). In some years, sei whales (*Balaenoptera borealis*) occur off of Southwest Greenland and between Southeast Greenland and Iceland

(Born *et al.*, 1998). Blue whales (*Balaenoptera musculus*) only occur sporadically in West Greenland, northward to Uummannaq, but are principally found between Paamiut and Sisimiut (Born *et al.*, 1998). The five species mentioned above are completely protected and are listed in CITES Appendix I (table 14).

Minke whales (*Balaenoptera acutorostrata*) are found along the entire west coast, both in open and sheltered water. Their distribution has become more coastal since the 1980s when they were abundant along the outer edges of West Greenland's fish banks. In recent years, they have become most abundant in Southwest Greenland. In East Greenland minke whales are found along large stretches of coast (Born *et al.*, 1998). Fin whales (*Balaenoptera phusalis*) are found in West Greenland, from Nunap Isua to Upernavik, both on the banks and in coastal areas, while in East Greenland, they are primarily found outside of the pack ice belt (Born *et al.*, 1998). The hunting of minke and fin whales in Greenland is by quota and internationally is considered to be aboriginal/subsistence catch. Minke and fin whales are listed in CITES Appendix II and I, respectively (table 14).

Beluga whales (*Delphinapterus leucas*) migrate along Greenland's west coast. In the spring they migrate across Baffin Bay to summer areas in northern Canada. Beluga whales are found from along the ice edge in Avanersuaq from early spring and the open water period until autumn. Beluga whales are rare in East Greenland. Several studies suggest that the beluga whale population has declined drastically and perhaps was halved from 1981 to 1994 (*e.g.*, see Heide-Jørgensen *et al.*, 1993; 1996). Hunting may have caused the decline. Beluga whales are listed in CITES Appendix II (table 14).

Like beluga whales, narwhals (*Monodon monoceros*) conduct yearly migrations. They are most abundant by the west coast and less so by the east coast. As indicated on map 39, narwhals winter under the dense pack ice in Baffin Bay, but can also be found closer to the coast on the west coast (Born *et al.*, 1998). During the summer, narwhals concentrate by Inglefield Bredning in Avanersuaq and Melleville Bay on the west coast and in the fjords by Ittoqqortoormiit, Kangerlussuaq and Tasiilaq/Ammassalik on the east coast (Born *et al.*, 1998). The narwhal is listed in CITES Appendix II (table 14).

Harbor porpoises (*Phocoena phocoena*) occur along Greenland's entire west coast, but are thought to occur primarily in the areas off Paamiut, Maniitsoq and Nuuk, and on rare occasions, by Southwest Greenland.

Several species are guests around Greenland in small numbers during the summer. Killer whales, or orcas, (*Orcinus orca*) visit Greenland's coasts up to Qaanaq and Ittoqqortoormiit, while bottlenose dolphins (*Hyperoodon ampullatus*) reach Qeqertarsuaq and Danmarkshavn during their regular summer visits. Long-finned pilot whales (*Globicephala melaena*) occur along Greenland's west coast in late summer up to Qeqertarsuaq, while white-sided dolphins (*Lagenorhynchus acutus*) and white-beaked dolphins (*L. albirostris*) are rare summer guests in the waters around South Greenland up to Sisimiut and Tasiilaq/Ammassalik.

## 4. *Protection and use of biological resources*



Signatories of the Biodiversity Convention are obligated to use biological diversity in a sustainable manner (Article 10, Anon., 1994a). Sustainable use entails exploiting biological diversity in a manner that does not lead to a long-term decline in biodiversity and thus, preserves the potential to meet the needs of present and future generations (Article 2, Anon., 1994a).

The Biodiversity Convention asks participating countries to develop national strategies and action plans for the preservation and use of biodiversity. It is recommended that nationwide studies should be the basis of the development of a country's national strategies and action plans.

Politicians and officials manage biological resources in Greenland. Their decisions are based partly on recommendations made by biologists. In the administration of Greenland's Home Rule regulations regarding fishing and hunting, emphasis must be placed on the conservation and restoration of resources, the most rational and seasonally-best exploitation of resources coinciding with customary biological advisories, economic and occupational considerations for professional hunters and fishermen, etc. It is also emphasized that knowledge from local hunters and fishermen should be gathered. Advisories are only given as guidance and how biological resources are managed therefore becomes a political decision.

In order to evaluate whether the exploitation of a resource is sustainable, detailed information on the resource's dimensions and renewal rate, as well as on the dimensions of its use, have to be obtained. It is also necessary to gather as much information as possible on the previous exploitation of a resource to estimate the potential of the resource in question in a given region. Historical data can be used to determine how a resource has been used previously and to what degree the biodiversity still shows signs of previous exploitation. This is valuable in understanding how a country's natural resources are used today and how they can be used most appropriately in the future, both in relation to the Biodiversity Convention and to the country's exploitation of resources in general.

In the previous chapters, the status of ecosystem and species diversity in Greenland has been discussed. This chapter summarizes Greenland's biodiversity and resource exploitation from a historical perspective, current threats to biodiversity in terms of space use, and what type of protection is in place.

### *4.1. Greenland's biodiversity from a historical perspective*

During the last ice age, most plant and animal species disappeared from Greenland, and when the ice started to retreat 12,500 years ago it left a landscape of bare boulders and raw mineral soil upon which only certain pioneer plants could grow (Fredskild & Böcher, 1999).

The immigration of plants and animals to Greenland has been relatively slow because the country is a rather isolated island. In addition, dispersal within the country is hindered by topographical conditions in which species must disperse along a narrow corridor of land between the ice and the sea, which is interrupted by glaciers in several places.

The history of plant invasion is known partly from the analysis of pollen in deposits from lake bottoms. Grasses, sedges and species of the heath family were some of the first species that arrived and that still are common in Greenland. Dwarf birch (*Betula nana*) arrived 9000 years ago in West Greenland and green alder (*Alnus crispa*) appeared at about the same time that the first humans immigrated to Greenland about 4500 years ago. The Inuit are not believed to have introduced many new species from Canada to Greenland, but several European plants were introduced by the Norsemen and their animals. Although new plant species are still immigrating to Greenland and others are altering their distribution due to climate variation, it is presumed that the majority of the species present today existed in Greenland when the Norsemen settled there around 985.

The immigration of animals to Greenland also occurred over a long period of time. A number of marine mammal species occupied the sea close to Greenland during the Ice Age and were therefore present along Greenland's coasts soon after the retreat of the ice. It can also be assumed that several bird species quickly became established. When the first people arrived in Greenland all terrestrial mammals found there today were present. This suggests that the occurrence of species 4500 years ago and thus, the potential biodiversity, was not very different from what it is today.

In the earliest societies human populations were so small that although they lived exclusively off hunting and fishing, it was not possible for them to overexploit wildlife populations. Biodiversity was therefore probably intact when the Norsemen settled in Greenland about 1000 years ago. Analyses of pollen from humus layers in South Greenland show that scrub growth was much more widespread before the arrival of the Vikings than later on. The changes were caused primarily because the Norsemen brought domestic animals with them, particularly sheep, which grazed away large sections of scrub growth in areas where the Norsemen settled. Scrub growth was replaced by grass and herb cultivation, which was more subject to erosion (Taagholt, 1981). One of these formerly lush valleys is still seriously eroded (Böcher, 1999). This is the first testimony of human induced change in Greenland's biotopes, and human influence on Greenland's biodiversity thus started about 1000 years ago. In addition, Norsemen introduced several plant and insect species from Scandinavia that still are found today.

The following examples of significant, non-sustainable use of biodiversity are from whaling in the period 1600-1900. Bowhead whales (*Balaena mysticetus*) have been hunted since the Thule peoples arrived around year 900, but this exploitation probably did not affect them significantly. With the arrival of European whalers in the 1600s, hunting was intensified and bowhead whales were hunted to the degree that they almost became extinct. Bowhead whales were protected in 1932 but the population only has 350 individuals, which is just a few percent of what the population size was at the beginning of the 1800s (Woodby & Botkin, 1993).

At the end of the 1800s and the beginning of the 1900s, 300-500 beluga whales (*Delphinapterus leucas*) were caught annually from South Greenland northward to and including the Nuuk area. However, only a few whales have been seen and caught in this area since 1930. Beluga whales have probably disappeared from South and Southwest Greenland because the whaling take has been so large that the groups occupying the region have been exterminated (Ryhdaahl & Heide-Jørgensen, 2001). Beluga whales have not returned to the region despite the fact that they have not been hunted south of Nuuk since 1945.

A more recent example of the non-sustainable use of biodiversity is murre hunting, particularly the spring and summer hunt, which has decreased or exterminated thick-billed murre (*Uria lomvia*) populations in the southern part of the breeding area in Greenland. The best-known example is the colony Salleg in Uummannaq, where 70,000 pairs used to nest. At the end of the 1960s the colony had been reduced to 7000 breeding pairs. Attempts were made to protect the murrens using short-term conservation regulations. However, these measures were limited and short-lived and the population continued to decline until there were only about 100 birds left on the mountain in the middle of the 1980s (Falk & Kampp, 2001). If the 100 birds on Salleg were completely protected, it would take 120 to 350 years for the population to reach 70,000 pairs again.

The abovementioned examples are all typical for biodiversity problems in Greenland, where the hunting/fishing of species or populations that regenerate very slowly, is the biggest problem. Other types of biodiversity problems are associated with the disturbance or destruction of biotopes, which will be discussed in the next section.

## 4.2. Area use and protection

### 4.2.1. Area use

The population density of Greenland is low, even if only the ice-free areas are included in the calculation the density is only 0.2 people/km<sup>2</sup>. For comparison, the population density in the United States is 29 people/km<sup>2</sup>, in Denmark, 124 people/km<sup>2</sup> and in the UK, 244 people/km<sup>2</sup>. Furthermore, Greenland's population is concentrated in large cities and settlements and only a few people live "out in the country", see section 1.3.2.

In Greenland transportation between cities and settlements occurs by plane, helicopter, boat or dog sled and there is therefore no infrastructure such as roads or railroads between cities or settlements. Roads are only found within cities and settlements, as well as between some sheep ranches in South Greenland. Large parts of the ice-free regions in Greenland are therefore uninhabited, without modern installations and devoid of human activity. In recent years there has been a tendency for people from cities to spend more of their free time outdoors. This means that more recreational cabins are placed in the open landscape and in 2000 there were approximately 1000 recreational cabins in Greenland. In a country with large expanses of wilderness, this is not a problem, but locally, especially in proximity to the large cities, care should be taken so they are not placed in areas with sensitive biotopes or species.

After cities and settlements with their associated airports, mining and mineral and oil exploration are the largest structural installations in Greenland. Mining started in the middle of the 1800s, but only on a limited scale until the middle of the 1900s. There have been three large and a number of small mines in use, but there has not been any mining in Greenland since 1990. (Johansen *et al.*, 2001). However, significant mineral exploration still occurs, which also requires some sort of structural installation. Mining and mineral exploration can disturb/damage animals and plant growth and pollute the environment, for example with heavy metals. The lead and zinc pollution by Maamorilik has been so great that inhabitants were told not to eat the mussels, ammassat, etc, from the area. Specific changes in biodiversity as a result of mining and mineral exploration have not been documented however. In order to minimize physical impacts on the terrain and vegetation and impacts on animal life, an environmental authorization, which follows a number of general guidelines, has to be given in connection with mineral exploration and the potential mining that follows. During the production phase, pollutants and the effects on wildlife are monitored regularly.

There have been eight exploratory oil drillings in Greenland, the majority of which were done at sea. Prior to the drillings, extensive seismic studies were carried out, but oil production still has not been established in Greenland (Boertmann *et al.*, 1998). Oil exploration on

land requires heavy machinery and sequesters large areas for structures and roads. At sea, drilling is done from a ship or platform. Seismic investigations scare animals both on land and at sea. Test drilling can lead to pollution with oil, which can have a large negative effect on the sensitive Arctic ecosystem. Before oil exploration can be commenced, an environmental impact assessment (EIA) has to be carried out in order to minimize impacts on wildlife.

Extensive sheep ranching occurs in South Greenland on an area of about 240,000 ha. Sheep ranching has had an impact on the environment in the past because sheep grazed birch forest and willow scrub intensively during the winter. Today sheep have to be confined to a barn in the wintertime, but since scrub and forest are eradicated to grow winter fodder, this may cause a greater stress on the biotope. Currently, the two areas with the most intact birch forest are in the Qinngua Valley and in Narssarssuaq. Neither of these areas have sheep. Birch forest and scrub are rare biotopes in Greenland (Due & Ingerslev, 2000).

As indicated above, it is only a limited part of Greenland's total area that is affected by development, industry and farming. However, there are still examples of damage and deterioration of biotopes over large parts of their distribution. It is therefore important to look at what types of protection presently exist for certain areas.

#### **4.2.2. Protected areas**

Greenland has an area of about 2.1 million km<sup>2</sup> and a coastline of about 40,000 km. Added to this is an approximately 0.3 million km<sup>2</sup> marine area. Most of the land area is covered by ice, but approximately 0.4 million km<sup>2</sup> are ice-free (Due & Ingerslev, 2000).

A large portion of Greenland's area has some form of protection. The world's largest national park is in sparsely populated Northeast Greenland and covers 956,000 km<sup>2</sup>. The majority of it is comprised of the Greenland Ice Cap. The park encompasses about 32% of Greenland's ice covered area and 43% of its ice-free area.

In the National Park everyone, except for individuals from Ittoqqortoormiit and Qaanaaq County, needs a permit to be in the region. Hunters from the two counties are permitted to hunt in the National Park. The Sirius Patrol and personnel from the permanent military and weather stations are permitted to hunt seals for dog fodder and to fish for private use. The Home Rule Government can also give permission to explore for minerals in the park.

In addition to the National Park, there are six other protected areas in Greenland (in accordance with Home Rule legislation no. 11 of 12 November 1989), which together cover about 8100 km<sup>2</sup>.

The nature reserve in Melville Bay was established primarily to protect wildlife associated with the marine environment, narwhals, beluga whales and polar bears. In one part of the reserve, professional hunters from counties adjacent to the reserve are allowed to conduct traditional hunting trips. All travel in the remainder of the reserve is prohibited.

Lyngmark on Qeqertarsuaq has been established primarily for the scientific studies carried out there by the University of Copenhagen. Although Lyngmark is protected, travel and hunting are not prohibited in the area.

The landscape in the valley Arnangarnuup Qoorua is composed of steppe and dwarf-shrub heath and is virtually untouched. Animals and plants are protected year round and only travel by foot is permitted in the area.

The largest area in Greenland with birch forest is found in the Qinngua Valley and the valley is protected to preserve this unique environment. Entry to the valley is not prohibited, but hunting and other activities that can harm the environment are.

Akilia is a small island that is protected to preserve its geological formations. The Home Rule Government can give permission for the collection of rocks and minerals for research purposes.

The newest protected area was established on the 25th of April 2000, when the inner part of Ikka Fjord was protected. The fjord is protected in order to preserve the unique Ikka Columns that rise off the sea floor (see section 2.3.8.1). There are restrictions on sailing with motorized boats, fishing with trawls, or other implements that may damage the columns, and collection and destruction of columns.

In addition to these protected areas, there are eleven areas in Greenland designated as Ramsar sites. Two of these are in the National Park. The remaining nine cover a total area of 12,500 km<sup>2</sup>. The aim of the Ramsar Convention is to protect important wetland and coastal ecosystems. With the accession of the convention, the participating countries commit to protecting the ecological value associated with designated sites and ensure their sustainable use.

The legislative protection of Ramsar sites will now be discussed. Each Ramsar site is designated as an "area important to wildlife" by the Bureau of Minerals and Petroleum (Egevang & Boertmann, 2001). With this designation a number of regulations related to mineral exploration have to be followed; travel within 5 km of a murre site in the breeding season is prohibited and flying with helicopters and fixed wing airplanes is restricted. Four of the sites that are designated as nesting bird reserves are additionally protected with a ban on hunting or travel, but for three of the sites, this is only for a small percentage of the area. However, the entirety of one of the sites is designated as a nesting bird reserve, with a ban on travel within 500 m of the area during the breeding season. A recent evaluation of the status of the sites recommends that additional protection of most of the Ramsar sites should be worked into the legislation (Egevang & Boertmann, 2001).

In the report "Naturbeskyttelse i Grønland" ["Environmental Protection in Greenland"] (Due & Ingerslev, 2000) a GAP analysis was carried out of environments and species that lack legislative protection to meet Greenland's obligations to the Arctic Council's network, the Circumpolar Protected Area Network (CPAN), for which each country must "...aim to provide relatively strict protection to areas in each ecozone..." (Anon., 1996g). The portion of the protected area in each ecozone was set at 12%, which is an indication of its original dimensions. The completed analysis is a simple calculation of the percentage protection in ecozones. The calculation shows that while the High Arctic region is well protected (44% of the area in the ecozone) because of the national park, Low Arctic and Subarctic protected areas are small and only cover respectively, 2.4 and 0.2% of the area in each region. In marine areas, these tendencies are even more common and are far from reaching CPAN's goals.

### **4.3. Sensitive environments in need of protection**

In the report "Naturbeskyttelse i Grønland" ["Environmental Protection in Greenland"] the need for protection of a number of sensitive environments and threatened and rare vascular plants is evaluated (Due & Ingerslev, 2000).

#### *Birch forest*

As mentioned earlier, birch forest has a very limited distribution and is under stress because of sheep grazing in South Greenland and earlier exploitation during the time of the Vikings. There are only two large areas where birch forest has not been impacted and perhaps additional large areas should be protected to ensure the long-term survival of birch forest in Greenland.

### *Homeothermic springs*

Homeothermic springs often have a unique flora and fauna in comparison to the surrounding areas and several plant and animal species in Greenland are only found in areas close to hot springs. The species *Limnognathia maerski* was the first species to be found from the class Micrognathozoa, and is still only found in the springs on Qeqertarsuaq, where the type specimen was found in 1994. Since 1994 only one new species in the class has been found and it seems that this class of animals has very few species, which is why the springs on Qeqertarsuaq are special and should be protected. In order to protect the unique environment around homeothermic springs from, for example, wear and tear from tourists, more areas with springs should be preserved or protected with occupation restrictions/regulations.

### *Saline lakes*

Although they are typically somewhat species-poor, saline lakes, like homeothermic springs, have a unique flora and fauna. Since saline lakes are rare and several of them are close to developed areas, Due & Ingerslev (2000) recommend that they should be placed under general protection.

### *Polynyas*

These ice-free areas in otherwise ice covered regions are very important for a number of marine birds and mammals. The polynyas are not presently protected in Greenland's legislation. However, efforts should be made in the future to protect them. Delimiting their boundaries is hampered by their seasonal variation in size, but since polynyas occur in the same place each year, this should not be a problem.

## **4.4. *Exploitation and protection of animal species***

Commercial exploitation of biological resources today is focused on a few species such as pink shrimp and Greenland halibut, while private and recreational exploitation is distributed over several species, from marine mammals and birds to char and caribou.

Below is a review of the species that are exploited. It must be emphasized that changes constantly occur in terms of which species are used, the population status of species and their regulation and management. The sections are organized identically; first a description of the species' distribution is given, then the hunting or fishing method is discussed and after this, the use of the species. Regulation of the species, the size of the catch, the population's status and if applicable, the unintended consequences associated with the use are discussed thereafter.

### **4.4.1. *Common eider (Somateria mollissima)***

#### *Species distribution*

Common eiders (*Somateria mollissima*) breed throughout Greenland, although only in small numbers around Qaqortoq and Paamiut. Several subspecies/races have been described and the race *borealis* occurs in Greenland and in eastern Canada, Iceland, Svalbard and Franz Josef Land (Boertmann, 1994).

#### *Hunting method*

The birds are shot with shotguns from dinghies or islets as they migrate past an area. The majority of birds are shot in the open water area by West Greenland (Frich, 1997a). Most common eiders are shot by professional hunters.

#### *Use of the species*

Common eiders are used in private households or sold at the local market. At one time eider down was collected from breeding areas and the sale of down to processing companies was an important source of income several places in Greenland.

### *Regulation of use*

There is no quota on the common eider take but there are rules regarding the types of transportation devices and weapons that can be used (Anon., 1989). Common eiders are protected in West, South and Southeast Greenland from the 1st of June to the 30th of September and in the rest of Greenland from the 1st of June to the 15th of August. In Qaanaaq and Ittoqqortoormiit County egg collection is allowed until the 25th of June. Driving rafts of moulting birds, which are unable to fly, is illegal (Anon., 1989). A few breeding sites are on Ramsar Sites (Anon., 1996a).

### *Catch size*

The most recent statistics from the hunting registry "*Piniarneq*" show that around 68,000-82,000 (1993-95) common eiders are shot per year throughout the country (Anon., 1997c). Of these, about 80% are shot in West Greenland's open water area (Frich, 1997a), which equals somewhere between 54,000 and 66,000 birds.

### *Population status*

A comprehensive estimate of the number of breeding individuals in Greenland does not exist since many of the breeding sites have not been visited and surveyed for several decades. The breeding population in West Greenland was estimated to be 10,000-100,000 breeding pairs in 1996 (Boertmann *et al.*, 1996). In the few breeding sites where population estimates have been made in more recent times, the results indicate that the breeding population has been drastically reduced (Frich *et al.*, 1998).

Common eiders are primarily non-migratory in Greenland and only conduct relatively short migrations coinciding with the formation of ice. West Greenland's entire common eider breeding population is thought to moult and winter in the open water area off West Greenland. The northernmost populations are thought to winter in the northern part of the open water area, while the majority of birds around Nuuk probably originate from breeding colonies in West Greenland south of Qeqertarsuup Tunua (Salomonsen, 1967). Birds from Canadian breeding sites supplement the population of wintering common eiders by Southwest Greenland, but the number of birds originating from these areas is still not known (Boertmann *et al.*, 1996). The recovery of a few ringed eiders in Southwest Greenland indicates that the Canadian race *v-nigra* is among the birds from Canadian breeding sites. Birds in breeding condition start to migrate towards breeding sites at the beginning of April. A number of non-breeding birds stay in West Greenland throughout the summer (Salomonsen, 1967).

Currently the size of the winter population of common eiders in West Greenland's open water area is more or less unknown. This is because the only existing study is one from the winter of 1988/89, where an attempt was made to quantify the population in the smaller parts of the open water area (Durinck & Falk, 1996).

Concern for Arctic eider populations has arisen in recent years among Arctic nations. The Arctic environmental collaboration Conservation of Arctic Flora and Fauna (CAFF) has decided that, after the thick-billed murre, the world's four eider species should have the highest priority in a joint management plan. The basis for this is, among other things, that the Canadians have found that Canada's breeding populations have declined sharply.

#### **4.4.2. King eider (*Somateria spectabilis*)**

##### *Species distribution*

In contrast to common eiders, king eiders (*Somateria spectabilis*) only breed in North and Northeast Greenland and exceptionally on the west coast in the northern part of Upernavik County. In autumn and winter, West Greenland is an important moulting and wintering area for breeding birds from North Greenland and, in particular, Canada. A number of juvenile and non-breeding king eiders stay on Greenland's west coast throughout the year (Boertmann, 1994).

### *Hunting method*

The birds are shot with shotguns from dinghies or islets as they migrate past an area. Most king eiders are shot by professional hunters.

### *Use of the species*

King eiders are used in private households and sold at the local market.

### *Regulation of use*

There is no quota on the king eider take, but there are rules regarding the types of transportation devices and weapons that can be used (Anon., 1989). King eiders are protected throughout Greenland from the 1st of June to the 15th of August (Anon., 1989). A previously very important moulting site for king eiders in Qeqertarsuup Tunua (Ramsar Area 385) is included on a Ramsar site (Anon., 1996a), but today is unimportant as a moulting site.

### *Catch size*

According to the hunting register "*Piniarneq*", the king eider catch only comprises a small part of the total yield from eider hunting in Greenland. In the years 1993-95, between 4018 and 5312 king eiders were shot nationwide, which equals about 6-7% of the total yield from eider hunting (Anon., 1997c, 1998). Studies of the species composition of eiders sold at the local market in Nuuk during the winter 1995/96 however, suggest that the proportion of king eiders is actually much larger. In a study period from the 1st of October to the 31st of May, king eiders comprised 32% of the birds sold at the local market in Nuuk (Frich, 1997b).

### *Population status*

The size of the breeding population in Greenland is more or less unknown. King eiders complete a special moulting migration right after the breeding season. Moulting sites, in contrast, are well known from several counts made by plane. The regions around southern Upernavik and Qeqertarsuup Tunua are unique in that in July and August, only males and immature birds arrive to moult (Salomonsen, 1967; 1968). About a month later, the females arrive in the region to moult and a small number of juveniles are present from the middle of September (Frimer, 1994b). Sometime in October all the birds have regained their ability to fly and move further south to wintering areas. It is unknown whether this happens as an actual southerly migration or if king eiders are forced south by the progressing ice in northern areas (Frich, 1997b). A significant number of king eiders that moult and winter off West Greenland originate from Canadian breeding populations, while the North Greenland population is thought to comprise a small proportion (Salomonsen, 1968). The spring migration toward breeding colonies starts at the beginning of April.

Key areas for the open water king eider winter population are known from counts made by plane in March-April 1981, 1982, 1990, 1991 and 1993 in connection with whale counts (Mosbech & Johnson, 1999). On the basis of these counts, it is estimated that about 280,000 king eiders winter on the banks off Southwest Greenland every year, with the greatest concentration on the banks Storehellefiskebanke and Fyllas Banke.

The study of eider species is highly prioritised by the Arctic environmental collaboration Conservation of Arctic Flora and Fauna (CAFF). As such, Greenland is responsible for improving fundamental knowledge on this topic, which is also necessary for reaching a sustainable use of this resource.

#### **4.4.3. Thick-billed murre (*Uria lomvia*)**

##### *Species distribution*

Thick-billed murres (*Uria lomvia*) occur along most of West Greenland, in Qaanaq County in North Greenland and in Ittoqqortoormiit County on the east coast. The open water area is a

wintering site for a number of Greenland's murre and likewise, for many murre that breed in Norway (Svalbard), Russia and Canada (Boertmann, 1994).

#### *Hunting method*

Thick-billed murre are shot with shotguns from dinghies and the majority of birds are shot during the winter in the open water area (Frich, 1997c).

#### *Use of the species*

Thick-billed murre are used in private households and sold at the local market. In addition to this, permission can be given for the sale of a limited number of birds during the winter in West Greenland south of Qeqertarsuup Tunua (Frich, 1997c).

#### *Regulation of use*

There is no quota on the thick-billed murre take, but recreational hunters are allowed to bring home a maximum of ten birds per hunt and to hunt them only for their own use. In addition to this, there are rules regarding the types of transportation devices and weapons that can be used for hunting (Anon., 1989). Thick-billed murre are protected in West, South and Southeast Greenland from the 15th of March to the 15th of October and north of Kangatsiaq County in West Greenland from the 1st of June to the 31st of August. In Qaanaaq and Ittoqqortoormiit County hunting is permitted year round. Egg collection is illegal. It is also illegal to shoot or create other unnecessary noise within 5 km of murre breeding colonies (Anon., 1989).

#### *Catch size*

According to "*Piniarneq*" somewhere around 188,000-200,000 (1993-95) murre are shot annually throughout the country (Anon., 1997c). About 85% of all murre reported killed in 1993 (194,984) were shot south of Qeqertarsuaq during the winter (October-March), which is equivalent to about 166,000 murre. However, studies of murre offered for sale at the local market in Nuuk in 1993, suggest that perhaps only half of the total murre catch is reported via "*Piniarneq*" (Fich, 1997). A number of Greenland's breeding birds continue their autumn migration over the Davis Strait to wintering areas off of Labrador and Newfoundland, where hunting also occurs.

#### *Population status*

The size of Greenland's thick-billed murre breeding population is well known and monitored regularly. The population status in 1998 suggested about 360,000 pairs breed in Greenland (GM & OC, 1993). Older calculations of population size are unreliable, but there is no doubt that Greenland's breeding population has decreased drastically in the last 60-70 years. The population decline has been particularly large in the region from Qeqertarsuup Tunua to southern Upernavik County. In Uummannaq County the previously large murre population has completely vanished, and in southern Upernavik and Qeqertarsuup Tunua the population has decreased to under a tenth of its former size. The largest, most stable murre populations occur in Qaanaaq County and northern Upernavik, and at present, these breeding sites support the largest portion of Greenland's breeding population (Kampp *et al.*, 1994).

The number of wintering murre in West Greenland's open water area is currently not very well known. Sporadic information regarding distribution and numbers was made available in connection with whale counts in 1981, 1982, 1990, 1991 and 1993 (Mosbech & Johnson, 1999). Marine bird counts made from ships during the winter of 1988/89 in parts of the open water area showed an even distribution of murre in the beginning of October in the region between Sisimiut and Paamiut, with the largest concentrations occurring 10.75 km from the coast. Later in the winter, murre were distributed closer to the coast and in February/March it was estimated that 170,000 murre occurred in a 6000 km<sup>2</sup> area southwest of Nuuk (Durinck & Falk, 1996).

The thick-billed murre is the most frequently hunted species in Greenland and hunting pressure is probably a major regulating factor for population size. Greenland's breeding population has been decreasing for several decades and hunting is most likely the major cause of this decline (Kampp *et al.*, 1994). Local differences in population dynamics suggest that hunting occurring in the summertime at breeding sites has contributed most to the decline. However, the majority of murre are shot in the wintertime in Southwest Greenland's open water area (Frich, 1997c).

Since its migration is a matter common to several Arctic nations, Greenland is responsible through the CAFF-Program for contributing to the monitoring and management of the murre population. In the Circumpolar Seabird Working Group, under the CAFF-collaboration, murre have received the highest priority and a joint management plan, International Murre Conservation Strategy and Action Plan, was put together and in 1996 approved by the environmental ministries of the Arctic nations.

#### **4.4.4. Arctic tern (*Sterna paradisaea*)**

##### *Species distribution*

Breeding Arctic terns (*Sterna paradisaea*) can be found all over Greenland, with the largest concentration along West Greenland. However, there are long stretches of coast where the species does not breed. For example, there are only three small breeding colonies on the stretch of coast between Nunap Isua and Paamiut (Boertmann, 1994).

##### *Hunting method*

Arctic tern eggs are collected in the breeding season by randomly searching Arctic tern colonies. All eggs are removed from localized nests (Frich, 1997d).

##### *Use of the species*

Eggs are collected for use in private households.

##### *Regulation of use*

Arctic terns are completely protected in Greenland. Egg collection, however, is allowed until the 1st of July (Anon., 1989). The island cluster Grønne Ejland in Qasigiannuguit and Aasiaat County is designated as a Ramsar site, partly because of its large Arctic tern population. This means that any activity and disturbance on the islands during the breeding season is illegal (Anon., 1996a).

##### *Catch size*

There are no figures for the total number of eggs collected each year, but egg collecting is a popular occupation in regions with terns. Egg collection after the 1st of July appears to be quite common in a colony on the island cluster Grønne Ejland in Qasigiannuguit and Aasiaat County, where a maximum of 10,000 pairs nested in 1996. Somewhere around 3000-6000 eggs were collected in the period up to the 25th of June (Frich, 1997d).

##### *Population status*

The latest counts from breeding colonies in West Greenland indicate that around 30,000 Arctic terns nest in West Greenland. There are probably many colonies that have not been documented yet and it has been suggested that the population contains somewhere around 30,000-60,000 breeding individuals. However, this does not include the approximately 25,000 breeding birds observed previously (1980) on Grønne Ejland. At one point the colony may have been the largest Arctic tern colony in the world (Boertmann *et al.*, 1996).

In June 1996 the Greenland Institute of Natural Resources (Grønlands Naturinstitut) completed a baseline study of the birds on Grønne Ejland and their use. This created a founda-

tion for potentially documenting any drastic future changes in size and species composition of the bird population. The Arctic tern population was estimated to be composed of about 5000 pairs with eggs in the middle of June. It was also estimated that a maximum of 10,000 pairs had attempted to breed. It was concluded that 1996 was a moderate to normal breeding year for Arctic terns, but it was also determined that the Arctic tern had disappeared as a breeding bird from the westernmost island, Angissat, where in 1980 there were 8000 pairs (Frich, 1997d).

#### **4.4.5. Caribou (*Rangifer tarandus groenlandicus*)**

##### *Species distribution*

Caribou (*Rangifer tarandus groenlandicus*) are found on Greenland's west coast. They are most abundant in the regions around Nuuk, Maniitsoq and Sisimiut (Map 10).

##### *Hunting method*

Caribou are hunted in inland regions. Hunters sail into fjords and go inland on foot to track them.

##### *Use of the species*

All meat from a kill must be used on the spot or brought home (Anon., 1997d). The meat is used in private households or sold locally. Hides are used for different types of clothing and in some areas as mats for sitting on on dog sleds. Antlers and hooves are used for crafting tupilaks (bone figurines) and jewellery.

##### *Regulation of use*

There is a quota on the number of caribou hunted and they can only be hunted with a permit. Individuals with a recreational or professional hunting license can apply for a permit. Recreational hunters that receive a permit are allowed to take one caribou while professional hunters are allowed to take two to six individuals depending on which county they are hunting in (Hansen, pers. comm.). The permit gives the number of individuals that can be taken and if applicable, which age class and sex the individual must be and the time period and area in which the hunt can take place (Anon., 1997d). Rifles with a minimum calibre of 0.222 must be used. Shotguns, semi- or fully-automatic rifles and gallery rifles cannot be used during the hunt. Dogs cannot be brought along and the use of dog sleds is not permitted (Anon., 1997d).

With the exception of the yearly hunting quotas set by local governments, caribou are protected throughout the country. Also, individuals that are equipped with satellite transmitters are protected (Anon., 1997d). Hunting is only permitted in the period from the 15th of August to the 10th of September and hunters have to submit various types of information regarding the hunt and the individuals killed (Anon., 1997d).

##### *Catch size*

Historically the number of caribou takes has fluctuated with decreases and increases in caribou population numbers (Vibe, 1967). During the period 1970-76 caribou hunting peaked with the number of reported kills reaching between 10,000 and 17,000 individuals per year (Anon., 1970-77). After hunting was closed in 1993 and 1994, the quotas in 1995, 1996 and 1997 were 2000, 2600 and 3111 individuals, respectively. The greatest hunting pressure occurs in the regions by Kangerlussuaq, Sisimiut and Nuuk (map 40).

##### *Population status*

Presently it is not known if caribou in West Greenland comprise a continuous population or several metapopulations. It is probable that metapopulations have originated because of geographical and topographical separation over long periods of time.

Caribou are known to fluctuate greatly in abundance worldwide. Historically the number of caribou in Greenland has increased and fallen several times (Vibe, 1967; Clausen *et al.*, 1980; Vibe, 1981d; Grønnow *et al.*, 1983; Roby & Thing, 1985; Vibe 1990b). Changes in population size among caribou are thought to be caused by the interplay among factors such as climate change, overgrazing, natural predation and hunting pressure.

In 1990 it was estimated that there were about 20,000 caribou in West Greenland, while in 1993 this figure fell to 10,000 (Hansen, unpubl.). The decline was probably caused by too great a hunting pressure (Nielsen, pers. comm.) and caribou were completely protected in 1993 and 1994. From counts in 1995, the number of caribou in West Greenland was estimated to be around 17,600 and the following year about 20,000. This means that the caribou population increased by about 7600 individuals during the protected period. It therefore seems reasonable to consider the exploitation of the species as a factor in explaining the low population numbers observed in 1993 (Nielsen, pers. comm.). However, it is currently not possible to estimate the influence of exploitation by humans on the abundance of caribou in West Greenland.

#### **4.4.6. Muskox (*Ovibus moschatus*)**

##### *Species distribution*

Muskoxen (*Ovibus moschatus*) occur naturally in Northeast and East Greenland. In addition to this, muskoxen have been translocated from these regions to the following areas in West Greenland: Kangerlussuaq; Ivittuut (Kangilinnguit); three places in Qaanaaq County (Avanaarliit, Iterlassuaq and Kangersuuk); Siguup Nunaa in Uummannaq and Upernavik County and Naternaq in Kangaatsiaq and Qasigiannnguit County (map 12).

##### *Hunting method*

Due to regulations, the length of the hunting season is limited. Summertime hunting occurs in August and September in Kangerlussuaq and Ittoqqortoormiit and in June and July in Ivittuut County. Wintertime hunting occurs in November and December in Ittoqqortoormiit County, in February and March in Kangerlussuaq and in November and March in Ivittuut County. Summertime hunting takes place in valleys in coastal regions since it is limited how far such a heavy animal can be carried. Wintertime hunting, however, takes place further inland. If the snow cover allows it, both dog sleds and snowmobiles are used for transportation to and from the hunting area in Kangerlussuaq.

##### *Use of the species*

Muskoxen were introduced to West Greenland to increase hunting opportunities for professional hunters. The introduced populations are also used for trophy hunting, where foreign hunters pay to hunt and shoot muskoxen. Trophy hunters receive the skull with the horns and hide, while the meat goes to the professional hunter that led the hunt. The law requires that all meat and hides from hunted muskoxen be brought home or stored (Anon., 1997e).

##### *Regulation of use*

There is a hunting quota on muskoxen and they can only be hunted with a permit. Individuals with a recreational or professional hunting license can apply for a permit. The permit gives the area and time period in which the hunt can take place and if applicable, which age class and sex the individuals must be (Anon., 1997e). The hunting seasons lie in the summer and winter during established time periods, while trophy hunting occurs in Kangerlussuaq outside of these periods (Anon., 1997e). Permit holders must submit various types of information regarding the hunt and the individuals they have killed (Anon., 1997e).

Only rifles with a minimum calibre of 6.5 x 55 can be used in the hunt. The ammunition must be fully capped (complete mantel) and semi- and fully-automatic rifles cannot be used. For trophy hunting, however, the minimum calibre is 7.62 mm (30.06) and ammunition other

than fully capped ammunition can be used. Planes, helicopters and any type of motorized vehicle cannot be used during the hunt or for transportation to and from the hunting grounds (Anon., 1997e). However, permits for using snowmobiles are given in certain regions by Kangerlussuaq and in Ivittuut County (Anon., 1997e). Dogs are not allowed to be brought along on the hunt in West Greenland. However, special permission can be given for the use of dog sleds by Kangerlussuaq for hunting related transportation (Anon., 1997e).

Muskoxen are protected in the National Park in Northeast Greenland (map 14), which encompasses 95% of their distribution. However, hunters on polar bear hunts in the area are permitted to kill muskoxen to feed to their dogs.

#### *Catch size*

Before 1956 muskox hunting was unregulated throughout the year in East Greenland north of Jameson Land and many individuals were captured and exported to zoos worldwide (Thing *et al.*, 1984). After 1956 the muskox capture was banned, and starting in 1958 a hunting quota was established in Ittoqqortoormiit County. However, many more individuals than allowed by law were taken (Thing *et al.*, 1984; 1987). The hunting area was reduced in 1974 with the establishment of the National Park. In Ittoqqortoormiit County the hunting quota was 250 muskoxen in both 1995 and 1996 (GS, 1997). Kill numbers have been provided up to 1997.

In 1988 hunting of introduced muskoxen in Kangerlussuaq was commenced with a quota of 200 individuals (Boertmann *et al.*, 1992; Olesen, 1993). Since then, there has been a quota of between approximately 300 and 600 individuals per year. Until 1992 only professional hunters from counties in Maniitsoq and Sisimiut shared the hunting quota. Since then, other counties have also received part of the quota for the summer season. Recreational hunters have been able to participate in the summer hunting season since 1994. In 1992 the first quota of six individuals was given for trophy hunting. Since then, the quota for trophy hunting has been between 18 and 40 individuals per year. In some years the quotas are not filled, while in other years information regarding the hunt is incomplete. In 1997 the quotas were 300 individuals for the summer hunting season, 200 individuals for the winter hunting season and 40 individuals for trophy hunting (Hansen, pers. comm.).

Muskox hunting in Ivittuut County started in 1995 with a quota of 23 individuals. In 1996 and 1997 the quotas were 20 and 30 individuals, respectively (Hansen, pers. comm.).

The populations in Avanersuaq, on the peninsula Siguup Nunaa and in Naternaq are currently protected. There are suspicions that in spite of their protected status, there are a number of illegal muskox kills in those areas.

#### *Population status*

##### *Original Population*

Muskoxen in North and Northeast Greenland (map 12) probably occur in approximately three metapopulations (Thing *et al.*, 1984). It is believed that muskoxen were increasing in abundance in the 1920s, 30s and 40s. Reports from expedition participants and hunters suggest that the population was growing until 1983 (Vibe, 1967). Several severe winters with many storms, deep snow and ice cover lead to a decline in the number of muskoxen, particularly in the winters of 1938-39 and 1953-54 (Vibe, 1967). In 1990 the number of muskoxen in North and Northeast Greenland was estimated to be between 9500 and 12,500 individuals (Boertmann *et al.*, 1992). Information is lacking on the relationship between muskoxen abundance and hunting pressure that would enable the evaluation of the influence of muskox exploitation by humans on the population. Hunters have reported that they must now travel for at least a week to hunt muskox, while they could previously be found within a day's travel of Ittoqqortoormiit (Nielsen, pers. comm.). If this is the case, it is an indication that there are fewer individuals or that they possibly have moved further away from areas inhabited by humans.

### *Translocated muskoxen*

All muskoxen in West Greenland have descended from original populations in Northeast Greenland. In 1962-65 27 muskoxen were translocated to an area by Kangerlussuaq (map 12). The population has been very successful and has grown. In 1987 1281 individuals were counted there (Aastrup *et al.*, 1988) and hunting was commenced that same year (Nielsen, pers. comm.). In 1993 there were about 4000 individuals in the region and around 2500-3000 in 1995 (Petersen, pers. comm.; Nielsen, pers. comm.). A total of approximately 4500-5000 muskoxen were killed in the period 1987-1997, an average of 500 individuals per year. Olesen (1993) suggests that 600 individuals should be killed per year to keep the muskox population under the threshold that would lead to overgrazing.

In 1987 fifteen muskoxen were translocated from Kangerlussuaq to Kangilinnguit in Ivittuut County (Nielsen, pers. comm.). In 1990 there were two groups of muskoxen totalling 42 individuals (Skolemose, pers. comm. in Boertmann *et al.*, 1992). The population seems to be stable and in 1997 about 150 individuals remained after the hunting season was over (Hansen, pers. comm.).

In 1986 muskoxen from the population by Kangerlussuaq were translocated to three different areas in Avanersuaq (map 12) (Vibe, 1986). In Avannarliit 14 individuals were released. Fifty individuals were observed in 1995 during an areal count (Nielsen, pers. comm.). In Ilerlasuaq six individuals were released and in 1997 the population comprised 47 individuals. The original flock appears to have split into at least two flocks. Several of the adults have had problems with their hooves because they do not migrate much and the substrate is very soft, preventing their hooves from being worn down (Burnham, 1996). Now that the muskoxen have split into flocks and are beginning to move over longer distances, their hooves may start to wear down in a normal fashion. All populations in Avanersuaq are protected and hunting is therefore not allowed.

In 1991 31 muskoxen were translocated to the Siguup Nunaa peninsula in Uummannaq and Upernavik County (Nielsen, pers. comm.). In 1995 36 individuals were observed (Nielsen, pers. comm.) and 28 in 1997, of which most of them were calves (Grønvold, pers. comm.). The population is probably increasing and still taking over new valley areas on the southern part of Siguup Nunaa (Grønvold, pers. comm.). The population is protected and hunting is therefore not allowed.

In 1993 31 muskoxen were translocated to Naternaq in Aasiaat Country (Nielsen, pers. comm.). The status of the population is not known.

### *Unintended consequences of use*

Human exploitation of muskoxen during the winter in the region Angujaartorfiup Nunaa by Kangerlussuaq may have a negative effect on the habitat because of snowmobile traffic associated with the winter hunting season. The region usually has a sparse snow cover and it is estimated that 20 cm of snow are necessary to prevent vehicles from damaging the terrain (Bay, pers. comm.). At present it is being discussed what alternatives can be implemented to minimize damage to the substrate and vegetation.

#### **4.4.7. Polar bear (*Ursus maritimus*)**

##### *Species distribution*

Polar bear (*Ursus maritimus*) distribution is primarily determined by the distribution of ice. Polar bears occur most frequently along Greenland's entire east coast and in Northwest Greenland. The occurrence of polar bears in Southwest Greenland varies since it depends upon the degree to which they follow the pack ice from East Greenland. By the coasts in the open water area between Paamiut and Nuuk, where there usually is no pack ice, and by Greenland's northernmost coast along the Arctic Sea, polar bears are rare (Born, 1995).

### *Hunting method*

The majority of polar bear hunting occurs on sledding trips in late winter and spring (February-April), but some polar bears are hunted from motorized dinghies, particularly in autumn (Born, 1995). Polar bears are shot with rifles. Sled dogs can act as important hunting partners and are used to hold back and distract the hunted polar bear.

### *Use of the species*

Polar bear meat is a highly valued source of food, which is partly due to the prestige in killing a bear and being able to dole out the meat to family and friends. The fat is used to make oil that keeps sealskin straps and whips soft and elastic, even in severe cold (Rosing-Asvid & Born, 1990). In Qaanaq County the majority of polar bear hides are used for local clothing; especially men's pants, but also for the rims of mittens and kamiks. The pants are a part of the boys' confirmation outfit (Rosing-Asvid & Born, 1990). Because of the traditional use of polar bear hides in Qaanaq County, only a limited number are sold to processing companies, while skulls and claws are sold to tourists (Rosing-Asvid & Born, 1990). In the remaining regions, local use of skins is limited and the majority are sold privately or to processing companies (Born, 1995).

### *Regulation of use*

There is no polar bear hunting quota in Greenland, but there are various restrictions (Anon., 1994b). Only individuals that are fulltime hunters with a valid professional hunter's license and registered sheep farmers are permitted to hunt polar bears. Planes, helicopters, motorized vehicles, such as snowmobiles, and vessels over 40 BRT may not be used during the hunt or as transportation to and from the hunting grounds. It is illegal to use poison, traps, foot snares and spring guns. It is also not permitted to use gallery rifles, shotguns and semi- or fully-automatic rifles. Polar bear kills and woundings have to be reported to the resident county along with certain information regarding the killed bear.

Solitary adult males can be hunted year round, while the remaining polar bears are protected from July to August; August to September in Tasiilaq/Ammassalik County. Females with cubs that are up to 12 months old are protected in all counties and females with cubs up to 24 months old are protected in all areas outside of Qaanaq, Upernavik, Tasiilaq/Ammassalik and Ittoqqoortormiit County (Born, 1995). In addition, important areas for polar bears (map 38) are protected by the Nature Reserve in Qimusseriarsuaq and the National Park in North-east Greenland, which are shown on map 14 (Born, 1995).

Greenland is obligated to manage its polar bears in collaboration with other polar bear nations under the Agreement on the Conservation of Polar Bears (Oslo Convention, 1973). Polar bears are listed in CITES Appendix II (table 14). The export of polar bear products from Greenland also requires a Greenlandic export permit in each case.

### *Catch size and population status in West Greenland*

The description of the polar bear's situation in the West Greenland, i.e. in central West Greenland and in Avanersuaq, is based on Anonymous (1996b). About five polar bears occur in Southwest Greenland per year (Born & Rosing-Asvid, 1989). In the rest of West Greenland polar bears are "shared" with Canada. There appear to be three more or less separate populations in, respectively, Kane Basin, Baffin Bay and the Davis Strait.

Population boundaries have been determined by radio-tracking polar bears over a number of years. Polar bears in the Kane Basin particularly stay in the Canadian areas of the region, while the population in Baffin Bay wanders between eastern Baffin island and the areas between Qimusseriarsuaq and Qeqertarsuaq. In the Davis Strait it seems as if some of the polar bears occur on the eastern edge of the strait's pack ice, i.e. off the central part of Greenland and northward to Qeqertarsuup Tunua.

In the Kane Basin there are approximately 200 individuals (1992-96), of which hunters from Qaanaaq County probably kill six per year. In Baffin Bay it is estimated that there are about 2200 individuals (1993-96). The current catch is about 117 individuals, of which an estimated 50 individuals are taken by Greenlandic hunters from Qaanaaq, Upernavik and Uumman-naq County and the regions south of there to about Sisimiut County. Canadians from the Broughton Island, Clyde River, Pond Inlet and Grisefjord communities also exploit the population. In the Davis Strait an estimated 950 polar bears were found in the 1970s, but today the population is comprised of approximately 1400 individuals. The catch is estimated to be about 57 individuals per year taken by Canadian hunters from Pangnirtung, Iqaluit, Lake Harbour, Labrador and Quebec. The catch more or less corresponds to the calculated sustainable take, although, the catch in Baffin Bay and the Davis Strait are slightly higher than the calculated sustainable take (Anon., 1997f).

#### *Catch size and population status in East Greenland*

The description of the human exploitation of polar bears in East Greenland is based on the IUCN's Polar Bear Specialist Group's 1993 (Born, 1995) and 1997 (Anon., 1997f) evaluation and on information given by Born (pers. comm.). Polar bears occur throughout East Greenland, probably in more or less separate groups. Marking studies in East Greenland and in Svalbard suggest that the exchange among polar bear populations is not very high in these areas.

The total size of the polar bear catch in East Greenland is not well known, but the average, based on Greenland's records for the years 1970-87, was 72 individuals per year. Since the reporting of kills has been incomplete, it is assumed at this time that about 100 individuals are taken per year. Hunting is more or less evenly distributed between Ittoqqortoormiit and Tasiilaq/Ammassalik County. At the IUCN's Polar Bear Specialist Group's meeting in Oslo in January 1997, it was concluded that the information from East Greenland was so inadequate that it was not possible to give the population (populations?) size (Born, pers. comm.). Since the actual take and the size of the exploited population is unknown, it is not possible to evaluate whether the populations in East Greenland are being used sustainably.

#### **4.4.8. Atlantic walrus (*Odobenus rosmarus rosmarus*)**

##### *Species distribution*

In Greenland Atlantic walrus (*Odobenus rosmarus rosmarus*) winter in two bank regions off central West Greenland (Born *et al.*, 1994) and off Northwest Greenland by banks and in the open water area North Water (map 22). By East Greenland walrus occur north of approximately 63° N. Their primary distribution occurs north of about 73° N. By East Greenland walrus winter in the open water areas along the coast (Born *et al.*, 1995; 1997).

##### *Hunting method*

The use of vehicles and the timing of the walrus hunt vary among the different regions. In Avanersuaq walrus are hunted year round, but only a few are hunted in August and the first half of September. The largest takes are from dinghies and fishing vessels in May-July and October. During the spring walrus are harpooned when they surface from the water. After this they are shot from new ice or the ice edge. According to local regulations, hunting from boats begins on the 15th of May when it is permitted to use motorized boats launched from the ice edge. This type of hunting occurs in the period June-July and the fall and ends when the formation of ice makes it impossible to manoeuvre a boat. Individuals are wounded so that they can be approached closely and harpooned; they are then killed with a bullet in the head. Walrus resting on ice floes are shot in the head and subsequently harpooned to prevent them from sinking if they fall into the water (Born *et al.*, 1995). In the regions by Uummannaq and Upernavik walrus are hunted equally from boats in autumn and from the ice edge in winter and spring. Hunting methods in central West Greenland are different from those in the remaining areas since larger vessels are used to hunt walrus on the West Ice

(Born *et al.*, 1995). In East Greenland walrus are normally caught in the period April-August at the entrance to the Scoresby Sound fjord network. They are either shot from land or from the ice edge. When they are resting on the ice, they are shot from dinghies with an outboard motor. Every year a few walrus are hunted in the Ammassalik region (Born *et al.*, 1997).

#### *Use of the species*

The meat, fat and skin are used mainly as dog food and a portion of the meat is used for human consumption. Walrus hunting is particularly important for hunters in Qaanaaq County. Here walrus products make up an estimated 25% of the meat and other edible products derived from hunting activities throughout the year (Born, 1987). Skulls with tusks are sold to tourists and tusks are also used for making crafts and tools (Born *et al.*, 1995).

#### *Regulation of use*

The regulation of walrus hunting is currently under revision. There is no hunting quota for walrus, but only professional hunters are allowed to hunt walrus. Hunting has to be done with dog sleds or vessels under 40 BRT. However, in certain cases special permission can be given for the use of snowmobiles. The lowest calibre allowed by law if using a rifle is 7.62 mm and only sharp-nosed ammunition (full mantle) can be used. Wounded walrus must be harpooned before they are put down to prevent them from sinking. All walrus takes have to be reported to the county of residence, along with various information regarding the killed individual (Anon., 1994c).

Walrus are protected year round in West Greenland south of 66° N. Traditional hunting is allowed in Upernavik, Qaanaaq and Ittoqqortoormiit County. From the 1st of June until the 31st of December, all walrus hunting is banned in West Greenland between 66° N and 75° N and females and their offspring in the same area are protected from the 1st of April to the 31st of December (Anon., 1994c).

Walrus are listed in CITES Appendix III and in Appendix II of the Bern Convention (table 14). This means that trade in walrus products is subjected to EU import regulations. Export of walrus products from Greenland requires a Greenlandic export permit for each case.

#### *Catch size and population status in West and Northwest Greenland*

As a whole, walrus hunting is not very well documented throughout Greenland. Furthermore, the number of losses, which are thought to encompass 25-30% of wounded individuals, is only partially documented (Born *et al.*, 1995). The total yearly take in central West Greenland, including losses, is estimated to be about 75 walrus, of which 50 of them are successful hunts. In the northern part of Baffin Bay the yearly Greenlandic/Canadian take is estimated to be 380 walrus, of which 280 of the hunts are successful (Born *et al.*, 1995).

Walrus in West and Northwest Greenland winter in two more or less separate areas in central West Greenland (between about 65° 30' N and about 70° 30' N) and in the North Water, i.e. the northern Baffin Bay and Smith Sound region between Avanersuaq and Eastern Ellesmere Island (map 22). Some, probably only a few, walrus can be found during the winter in the open water furrow between fast ice and pack ice in Uummannaq and Upernavik County (Born *et al.*, 1995).

In 1995 the North Atlantic Marine Mammal Commission (NAMMCO) conducted an evaluation of the status of the Atlantic walrus following a request from Greenland (NAMMCO, 1995). Final and reliable estimates of the size of exploited walrus populations in central West Greenland and northern Baffin Bay still have not been made. This makes it difficult to say whether or not walrus hunting is occurring at a sustainable level. However, there is no doubt that the number of walrus in central West Greenland has dropped drastically during the last 100 years (Born *et al.*, 1994; 1995). In this area, a number of adult females have been killed

during their protected period in spite of the ban since 1956 (Born *et al.*, 1994). Since the 1960s, an increasing number of dinghies with greater power have been used for walrus hunting in Avanersuaq, and this probably means that hunting pressure in the area has increased. In all areas, hunters selectively kill larger individuals (larger tusks, more meat). This means that hunting is particularly directed at adult, reproductive individuals. This type of hunting poses a particular risk for the population since the survival of adult, sexually mature individuals, especially females, is the most important factor for the persistence of walrus and other large mammal populations.

#### *Catch size and population status in East Greenland*

In east Greenland walrus are found along the entire coast from about 63° N to about 81° N. Their main distribution however is north of about 73° 30' N (map 22). The population in East Greenland is isolated from the populations by West Greenland region and are probably only connected to a small degree with individuals by Svalbard-Franz Josef Land and in the Davis Strait (Born *et al.*, 1995).

Because of hunting up until the middle of the 20th century the population decreased sharply. Walrus disappeared from several haul-outs and beginning in 1965, walrus were totally protected north of Ittoqqortoormiit in the area that today is the National Park (Born *et al.*, 1997).

In recent decades an estimated 25 walrus have been killed annually in the regions from the entrance to Ittoqqortoormiit and southward. This figure comprises a loss of about 23%. A minority of these individuals are taken in Tasiilaq/Ammassalik County. Information regarding the take by Ittoqqortoormiit shows that particularly adult males are hunted in this region. Theoretically a population of 500-1000 walrus can survive a yearly reduction (hunting plus loss) of between 10 and 50 individuals (Born *et al.*, 1995). The current estimated walrus take is probably sustainable. Reports from hunters in Ittoqqortoormiit that walrus have become more common at the entrance to Scoresby Sound since they were protected, is thought to be an indication that the population has been increasing since its protection.

#### **4.4.9. Ringed seal (*Phoca hispida*)**

##### *Species distribution*

Ringed seals (*Phoca hispida*) occur in all of the waters surrounding Greenland. The most proximate occurrences are in Northwest and East Greenland.

##### *Hunting method*

The majority of hunting occurs in Northwest and East Greenland. About half of the total take is hunted during the winter in nets under the ice (Anon., 1995a). However, hunting with nets becomes less effective relative to the increase in light during the spring. During this time of year, more seals haul-out onto the ice to sunbathe (Utuut) and hunting activities in April-May are particularly directed toward these individuals and individuals swimming in furrows and other openings in the ice (ice edge hunting) (Christiansen, 1983; Teilmann & Kapel, 1996). In May the majority of the year's young leave their natal dens and are taken during hunts, which peak at this time of year (Christiansen, 1983; Anon., 1993; 1994d; 1995a). A number of ringed seals are shot from dinghies during the summer and fall, but aside from northwestern Greenland, this take is very limited. Professional hunters are responsible for the majority of the total seal take (Anon., 1993; 1994d; 1995a).

##### *Use of the species*

Seal meat is used both for human consumption and as dog food and skins are sold for processing. Before the anti-sealskin campaigns at the beginning of the 1980s, ringed seal skins were an important export and the basis of existence for the majority of hunters in North and East Greenland. Therefore, when the hides lost their value their purchase was continued,

now with a massive supplement. This practice continues today and the hunting of seals is still the primary source of income for a number of settlements.

#### *Regulation of use*

There are no restrictions on the hunting of ringed seals except for a number of local regulations that particularly protect summer localities. In addition, there is the general protection given by the National Park in North and Northeast Greenland and the wildlife reserve in Qimusseriarsuaq (map 14). Regulations that prohibit or limit motor boat traffic or the use of snowmobiles in particular fjords also provide a certain level of protection.

#### *Catch size*

The hunting registry, which started in 1954, shows a steady increase in the ringed seal take from about 35,000 individuals in 1964 to 60,000-70,000 individuals in the middle the 1960s. Since then, the take has been more or less stable with a few large fluctuations (up to  $\pm 25,000$  individuals).

#### *Population status*

Ringed seals have a circumpolar distribution. In the Sea of Okhotsk and the Baltic Sea they are cut off from the rest of the ringed seal population, but beyond this, there is no reliable information on possible population divisions or sizes. Therefore, it must be assumed that various physical barriers create more or less disjunct populations. Whether there is a noteworthy mixing of ringed seals from East and West Greenland is still an unanswered question. However, there are several accounts of ringed seals swimming back and forth between East Canada and West Greenland (Teilmann & Kapel, 1996) and it is possible that ringed seals from these regions should be considered part of the same population.

In 1996 a work group established by the North Atlantic Marine Mammal Commission's (NAMMCO) scientific committee concluded that Greenland's current ringed seal take was sustainable (Teilmann & Kapel, 1996). Three of the most substantial arguments in for this assumption are that the current hunting pressure has been maintained for a number of years without visible signs of a decline in the population(s), that Greenland's take is particularly made up of males and very young individuals and that the ringed seal's very wide and even distribution across most of the Arctic limits large-scale overexploitation.

#### **4.4.10. Harbour seal (*Phoca vitulina concolor*)**

##### *Distribution*

Harbour seals (*Phoca vitulina concolor*) have been documented in all inhabited areas in Greenland, although only rarely north of Tasiilaq/Ammassalik County on the east coast and north of Upernavik County on the west coast.

##### *Hunting method*

In the first half of the 20th century there were several harbour seal haul-outs where hunting occurred regularly (Teilmann & Dietz, 1993). In the meantime, these seals have become so rare that the majority of takes are spontaneous, i.e. they occur when the opportunity arises.

##### *Use of the species*

Skins are used for "women's pants" in West Greenland's traditional national costume.

##### *Regulation of use*

Adult harbour seals are protected from the 1st of May to the 1st of October. In addition, there are local regulations that protect certain haul-outs in Paamiut and Qaqortoq County from hunting and disturbance.

### *Catch size*

Throughout Greenland, with the exception of Nanortalik County, hunting decreased sharply in the 20th century. The yearly catch at the beginning of the last century was around 1000 individuals (Winge, 1902), but this has fallen steadily. According to hunting statistics, only about 40 individuals were taken per year in the 1980s. The new hunting registration system (*Piniarneq*), where recreational hunters also report their takes, started in 1993. Here the yearly reported harbour seal takes for 1993, 1994 and 1995 were 274, 278 and 266 individuals, respectively (Anon., 1993; 1994d; 1995a). However, erroneous reports have been found where ringed seals have been reported as harbour seals and it is very probable that these numbers are too high. In the same years 13, 38 and 33 harbour seal skins, respectively, were purchased by Great Greenland Trading Company. Respectively, 3, 14 and 19 of the skins were from Greenland's southernmost settlement, Aappilattoq.

### *Population status*

In Greenland it is unknown whether there is one or several harbour seal populations and if there is any mixing with neighbouring populations in Canada and Iceland. The large decrease in hunting in the 20th century and the awareness that several haul-outs are no longer used or only used by very few individuals (Teilmann & Dietz, 1993), is a clear sign that there is an overall decline in harbour seal abundance by Greenland. It has been suggested that climate change may be a cofactor in the population's decline (Kapel & Petersen, 1982). However, Teilmann and Dietz (1993) point out that various sources indicate that the population has been decreasing for close to a century independent of climate variation. They suggest that increased hunting pressure and boat traffic and the increasing number of seals caught in char and salmon nets, may be factors in the decline.

#### **4.4.11. Bearded seal (*Erignathus barbatus*)**

##### *Species distribution*

Bearded seals (*Erignathus barbatus*) usually occur singly and are not abundant anywhere. However, they are evenly distributed throughout most of the Arctic.

##### *Hunting method*

Bearded seals are hunted in all inhabited areas of Greenland. However, most of the hunting occurs in Northwest and East Greenland. In the open water season bearded seals are usually hunted from dinghies or small boats, but in the winter and the early spring, a few are caught using "breathing hole hunting" – harpooning and killing by one of the seal's breathing holes.

##### *Use of the species*

Bearded seals are particularly sought after in hunting districts because of their thick but elastic skin, which is used for kamik soles, straps, dog whips and other such items.

##### *Regulation of use*

There are no restrictions on bearded seal hunting in Greenland.

### *Catch size*

The hunting registries from 1954 to 1985 report a steady take of 500-1000 individuals per year, while the new system "*Piniarneq*", which also includes hunting by recreational hunters, reports an annual take of between 1800 and 1900 individuals for the years 1993, 1994 and 1995 (Anon., 1993; 1994d; 1995a).

### *Population status*

Bearded seals have a circumpolar distribution. Some researchers believe that bearded seals by the Bering Sea and the Sea of Okhotsk are so different from the bearded seals by the Laptev Sea, Barents Sea and the North Atlantic Ocean, that there are two subspecies. This

issue has not yet been resolved. Whether Greenland has more or less disjunct populations is unknown. Therefore, it is not possible to determine the population(s) status, but as with the ringed seal, the bearded seal's very wide and even distribution is probably a buffer that limits large-scale overexploitation.

#### **4.4.12. Harp seal (*Phoca groenlandica*)**

##### *Species distribution*

Harp seals (*Phoca groenlandica*) give birth to their offspring in February-March on dense pack ice concentrations in three regions: in the White Sea in northern Russia, in the Greenland Sea around Jan Mayen and by Newfoundland. After their annual shed, which occurs in about the same areas as where the young are born, harp seals disperse out over the northern Atlantic Ocean. Harp seals arrive in Southwest Greenland in large numbers in May-June and later, during the summer and fall, disperse along the coasts northward to Qaanaaq and Ittoqqortoormiit County. In the late fall harp seals leave the northern regions and most go back to the breeding sites, some however, primarily young animals, winter in the waters of the Arctic.

##### *Hunting method*

Harp seals are hunted throughout Greenland. The majority of hunting occurs during the summer when the conclusion of mating and shedding in regions around Newfoundland, Jan Mayen and the White Sea, lead to large-scale forage searches in most of the Arctic. Hunting occurs almost exclusively with dinghies and rifles and there are probably quite a few seals that sink before they can be hauled up. This is especially true in the pre-summer period when harp seals are very lean.

##### *Regulation of use*

There are no restrictions on harp seal hunting in Greenland.

##### *Catch size*

Harp seal hunting in Greenland was subjected to major changes in the 20th century. According to commerce and hunting statistics, the number of harp seals caught per year dropped from 20,000 in the 1940s to 6000-7000 at the end of the 1960s, and then rose to 15,000-20,000 in the beginning of the 1980s. There are no reliable hunting statistics from the period after this, but it appears that hunting continued to rise. The new hunting statistic "*Piniarneq*" indicates that the take in 1993-95 was somewhere around 50,000 harp seals per year, of which about 10,000 were reported by recreational hunters (Anon., 1993; 1994d; 1995a).

##### *Population status*

After the breeding season harp seals disperse throughout the entire northern Atlantic Ocean. However, studies have shown that only a small portion of the breeding population by Newfoundland and Jan Mayen moves into the waters surrounding Greenland. The most recent scientific evaluation concluded that the production of offspring by Newfoundland increased from about 580,000 in 1990 to about 700,000 in 1994, corresponding to a total population size of about 5 million harp seals in the northernmost Atlantic Ocean (Anon., 1995b). The status of the population by Jan Mayen is not as well known, but it is much smaller than the Newfoundland population. It is estimated that the production of offspring presently is on the order of 60,000 offspring per year, corresponding to a population size of about 350,000 harp seals. However, it is not clear if this population is stable or increasing. The majority of the 50,000 harp seals hunted in Greenland are taken from the Newfoundland population, which in spite of a Canadian take about as large as Greenland's, has increased significantly in recent years. In 1996 the Canadians started in earnest to hunt harp seals commercially again and had a take of about 250,000 individuals, which is considered sustainable according to the recommendations given by the International Council for the Exploration of the Sea/North West Atlantic Fisheries Organization's (ICES/NAFO) working group for harp and hooded seals (Anon., 1995b).

#### 4.4.13. Hooded seal (*Crystophora cristata*)

##### *Species distribution*

Hooded seals (*Crystophora cristata*) give birth to their offspring at the end of March on pack ice concentrations in three regions: in the Greenland Sea around Jan Mayen, in the middle of the Davis Strait and by Newfoundland. Hooded seals from the latter two breeding sites migrate to West Greenland and Arctic Canada as well as Southeast Greenland and the Denmark Strait. Individuals from the Jan Mayen region primarily occupy the eastern part of the North Atlantic. In mid-summer, from the middle of June to the end of July, hooded seals gather on pack ice to complete their annual shed. There are two known shedding sites: one north of Jan Mayen and one in the Denmark Strait. After shedding, hooded seals disperse across large parts of the northern Atlantic Ocean. Hooded seals from Jan Mayen usually remain east of Greenland and existing data suggest that the hooded seals caught in Greenland almost exclusively originate from Newfoundland and the Davis Strait, and not from the Jan Mayen population.

##### *Hunting method*

Hooded seals are hunted in all inhabited areas of Greenland, although rarely in Ittoqqortoormiit and Qaanaaq County. Hunting generally occurs from dinghies or small motorboats. In West Greenland, hunting primarily occurs in the time period between the breeding and the shedding season (April, May, June). In East Greenland, hunting occurs almost exclusively in connection with shedding in the month of July.

##### *Use of the species*

Adult hooded seal skins were previously used as covers for umiaks (women's boat) and kayaks. Today it is skins from young hooded seals in particular that are of high value in the fur industry.

##### *Regulation of use*

There are no restrictions on hooded seal hunting in Greenland.

##### *Catch size*

From 1960 to 1985 the yearly hooded seal take rose from about 1200 to 5000-6000 individuals and the new hunting statistic "*Piniarneq*" (1993-95) reports an annual take of about 7000-8000 individuals (Anon., 1993; 1994d; 1995a).

##### *Population status*

The number of hooded seal offspring in the Newfoundland region is based on counts in 1984 and 1990 and is estimated to have been about 63,000 and 84,000 young, respectively. Due to the uncertainty of the two results however, they are not significantly different from each other. Analogous studies in the Davis Strait region were only carried out in 1984 and gave an estimated number of offspring in this area of about 19,000. It should therefore be assumed that the total hooded seal production in the northwest Atlantic is presently at least 84,000, corresponding to a population size of about 350,000 hooded seals (Anon., 1995b). The size of the population in the northeast Atlantic Ocean (the Jan Mayen population) is not precisely known, but is estimated to be smaller than the northwest Atlantic population and, as mentioned, is not of great importance to Greenland's take. Despite an increasing take by Greenland, the population seems to be able to withstand the hunting pressure. This should be viewed in connection with the fact that the commercial hunting of hooded seals by the Canadians has been almost non-existent since the 1980s.

#### 4.4.14. *Beluga whale (Delphinapterus leucas)*

##### *Species distribution*

Beluga whales (*Delphinapterus leucas*) migrate along Greenland's west coast. In the spring they migrate across the northern part of Baffin Bay to summer sites in North Canada. In Av-ernasuaq beluga whales occur along the ice edge early in the spring and through the fall in the open water period. Beluga whales are rare by East Greenland (Anon., 1995c).

##### *Hunting method*

Beluga whales are shot with rifles during drives in open water, along the ice edge and in the so-called "sassat" (ice entrapment). Hunts with nets also occur. The largest takes in Qaanaaq County occur in the month of September when beluga whales come from Canada on their way south. Later in October they are hunted in Upernavik and from November to May, they are taken in Qeqertarsuup Tunua and as far south as Sisimiut and Maniitsoq. Until around 1930 most beluga whales were taken in Southwest Greenland. Since this time however, the majority of hunts have gradually been occurring further north. Since the 1970s the largest takes have been made with drives in Upernavik in autumn, but large takes still occur in Qeqertarsuup Tunua (among other things with sassat) and off Sisimiut in the spring (Heide-Jørgensen, 1994). In East Greenland beluga whales are rarely seen or caught.

##### *Use of the species*

Mattak (skin with the underlying layer of blubber) is a popular delicacy that like the meat is eaten locally and sold to cities in South Greenland, which do not practice beluga whale hunting.

##### *Regulation of use*

Individuals with a professional or recreational hunting license are allowed to hunt beluga whales. Killing, wounding and secondary killing of beluga whales must be reported to the resident county as quickly as possible. It is illegal to use explosives, harpoon guns, shotguns and gallery rifles during the hunt. Rifles must have a minimum calibre of 7.62 mm, although rifles with a smaller calibre may be used for putting down the whale after securing it with a harpoon or net. When using nets to catch the whales, the net must be checked within 24 hours. It is illegal to hunt beluga whales by encircling them in a boat. In the ice entrapments ("sassat"), killing must be effective and take place as quickly as possible and flensing of the whale must take place as soon as it has been hauled up. Hunters are not allowed to kill more than can be brought home by dog sled and all edible parts must be taken home or stored. Planes, helicopters and any type of motorized vehicle cannot be used during the hunt or as transportation to and from the hunting site (Anon., 1995b). It is permitted to hunt and sell products from beluga whales using vessels of 25 BRT/18 BT and under. With vessels greater than 25 BRT/ 18 BT and up to 50 BRT/ 50 BT one can hunt whales for personal use but not to sell. A maximum of two whales can be caught from vessels over 50 BRT/ 50 BT and up to 79.9 BRT/ 210 BT to be used as provisioning during sailing. It is illegal to hunt beluga whales from vessels greater than 79.9 BRT/ 210 BT. Vessels larger than 25 BRT/ 18 BT cannot be used as a mother ship for smaller vessels engaged in the hunt nor can they be used in connection with flensing and transporting the kill (Anon., 1996c). Beluga whales are protected in the waters encompassed by the National Park in North and East Greenland and the Nature Reserve in Qimusseriarsuaq (map 14); however, certain rules pertain to the residents of Upernavik, Qaanaaq and Ittoqqortoormiit Counties (Anon., 1995d).

Beluga whales are listed in CITES Appendix II (table 14) and the export of beluga whale products is regulated by CITES. A permit from Greenland's Home Rule Government is required to be able to export products derived from this species.

### *Catch size*

The beluga whale take is 600-700 whales per year. During the 1980s there was a tendency for hunts to last longer and longer toward the north (Heide-Jørgensen, 1994). Very few beluga whales are taken in East Greenland.

### *Population status*

Results of several studies suggest that the beluga whale population declined drastically during the 1980s, probably due to hunting. The population was possibly reduced to half its size from 1981 to 1994 (Heide-Jørgensen *et al.*, 1993; Heide-Jørgensen & Reeves, 1996). The latest studies show that the population may have been reduced by 60% within the past 20 years (Rydahl & Heide-Jørgensen, 2001). Since 1930 only a few beluga whales have been caught along South and Southwest Greenland. Beluga whales probably disappeared from South and Southwest Greenland because the hunting pressure was so great that the groups occupying the area were extirpated (Rydahl & Heide-Jørgensen, 2001).

The calculated sustainable beluga whale take in West Greenland is currently significantly smaller than the actual take. In 1997 the scientific work-group the Joint Commission for the Conservation and Management of Narwhal and Beluga (JCCM) and the Greenland Institute of Natural Resources (Grønlands Naturinstitut) recommended that the hunting of beluga whales should be drastically reduced. It has been recommended that the take should be reduced to fewer than 200 individuals to ensure it is sustainable. In 2001 JCCM and the North American Marine Mammal Commission (NAMMCO) suggested that takes should be reduced as quickly as possible to 1000 individuals per year to halt the decline of the beluga whale (Anon., 2001). Possible limitations on hunting include quotas, restrictions on implements used during the hunt (*e.g.*, hunting only allowed from fishing vessels under 20 BRT) and hunting region restrictions (*e.g.*, reduction of takes where many females occur). It is not possible to protect reproductively mature females since they cannot be discriminated from reproductively mature males.

#### **4.4.15. Narwhal (*Monodon monoceros*)**

##### *Species distribution*

In March narwhals (*Monodon monoceros*) can be found under the pack ice in the central Davis Strait and the southern part of Baffin Bay. During the winter and spring they occur along the coast of West Greenland, where they are particularly abundant by the southern passage to Qeqertarsuup Nunua. They are rare south of Aasiaat. Some narwhals winter in the North Water in the northern part of Baffin Bay. During the summer they are particularly common by Kangerlussuaq in Qaanaaq County and in Qimusseriarsuaq (map 39). Narwhals are common in Upernavik and Uummannaq County in autumn (Heide-Jørgensen, 1994). The fjord networks Sermilik, Kangerlussuaq and Kangertiitivaq in East Greenland are important sheltered water summer regions where narwhals occur from about May to November. During the winter they can also be found at the entrances to the abovementioned fjords and probably also occur under the pack ice between Greenland and Svalbard (Dietz *et al.*, 1994).

##### *Hunting method*

Narwhals are hunted from kayaks, with nets and along the ice edge in Qaanaaq County. In the remainder of West Greenland they are shot from the ice edge and from dinghies in open water or caught in nets. In Qaanaaq County a large number of narwhals are hunted regularly from May to September with the largest takes in July-August. In Upernavik narwhals are hunted from the ice edge in the spring and again in October-November before the formation of the ice layer. In Uummannaq the largest number of narwhals are taken in November. In addition to this they are taken in "sassat" (ice entrapments) during the winter and spring along the ice edge. In Qeqertarsuup Tunua narwhals are hunted by Kitsissuarsuit and Qeqertarsuaq and in sassat from November to May (Heide-Jørgensen, 1994; Siegstad & Heide-Jørgensen, 1994).

In East Greenland narwhals are harpooned from kayaks or shot from dinghies with outboard motors. They are also shot from land, caught in nets or driven into shallow water where they are shot. They are hunted from February to December with the greatest takes from July to September. Kangerlussuaq is the most important hunting region in Southeast Greenland. Here hunting occurs between May and September, with the greatest take occurring in July (Dietz *et al.*, 1994). At the entrance to Kangertitituaq narwhals are hunted between April and July, where they are shot from the ice edge or from dinghies (Dietz *et al.*, 1994).

#### *Use of the species*

Mattak (skin with the underlying layer of blubber) is a popular delicacy that like the meat is eaten locally and sold to cities in Southwest Greenland, which do not practice narwhal hunting. The meat is dried for human consumption and a portion of the meat is used as fodder for sled dogs. Narwhal teeth are sold to processing companies or locally, where they are used for making crafts and tools such as harpoons (Dietz *et al.*, 1994).

#### *Regulation of use*

The same restrictions apply for narwhals as those for beluga whales (see section 4.4.14., Anon., 1995; 1996c). In Avanersuaq local regulations regarding the use of implements for hunting have been adopted to preserve the kayak hunting and harpooning of narwhals, which at the same time keeps the number of losses low.

Trade in narwhal teeth outside of Greenland is regulated by CITES. Narwhals are listed in CITES Appendix II (table 14). The European Union has tightened the CITES regulations (EURO-CITES) by prohibiting any import of narwhal teeth. However, the export of narwhal teeth from Greenland to Denmark, from where the teeth can be exported within the EU, is permitted.

#### *Catch size*

The most stable narwhal takes occur in Qaanaaq County, where about 200-300 narwhals are killed annually. In Uummannaq the number of takes varies between 100 and 300 individuals per year and one year was 1000 individuals. In addition to this, narwhals are hunted in Upernavik and in Qeqertarsuup Tunua, but in much smaller quantities. A large number of narwhals, i.e. over 100 individuals, are taken only when the whales are caught in an ice entrapment ("sassat") in Qeqertarsuup Tunua (Siegstad & Heide-Jørgensen, 1994).

It is estimated that the total take in East Greenland has been around at least 80 whales per year from 1981 to 1990, with the yearly take per county equalling about 50 whales in Tasiilaq County, of which 20-30 per year were taken around Kangerlussuaq, and 10-20 whales in the Ittoqqortoormiit region (Dietz *et al.*, 1994).

#### *Population status*

At present the status of narwhals in Greenland is being re-evaluated by the Joint Commission for the Conservation and Management of Narwhal and Beluga (JCCM) (Anon., 1997g). At present it seems that exploitation of the species is not of any major concern. However, studies are under way to investigate if there are several segregated populations in Baffin Bay. If this is the case, they should be managed separately. Future management initiatives for narwhals must await the suggestions given by JCCM, which in turn must wait for the results of biological studies that are underway. Possible limitations on hunting can be made in the form of quotas, restrictions on implements used during the hunt (*e.g.*, hunting only allowed from fishing vessels under 20 BRT) and hunting region restrictions (*e.g.*, reduction of takes where many females occur). It is also possible to protect adult narwhals that do not have teeth, which on the whole would protect females.

#### **4.4.16. Minke whale (*Balaenoptera acutorostrata*)**

##### *Species distribution*

Minke whales (*Balaenoptera acutorostrata*) occur along Greenland's entire west coast, both in sheltered and open (unsheltered) waters. They were present in small numbers along the outer edge of the banks Disko Banke, Store Hellefiskebanke, Lille Hellefiskebanke and Fylla Banke up until the middle of the 1980s. Since then however, their distribution has been more coastal. In recent years minke whales have been most abundant in Southwest Greenland. In East Greenland minke whales are found near the coast, especially by Tasiq and Ittoqqortoormiit (Anon., 1995c).

##### *Hunting method*

Minke whales are hunted either from fishing vessels with a harpoon gun or in communal hunts with participants in several small boats. In the communal hunts, whales are shot with handheld harpoon guns and rifles. Along East Greenland all hunts are communal hunts (Anon., 1997h). After the kill the whales are kept afloat with buoys and towed to a suitable flensing place on land.

##### *Use of the species*

Minke whales are not hunted commercially in Greenland and the International Whaling Commission (IWC) defines its minke whale catch as an "aboriginal/subsistence catch". It is illegal to commercially export minke whale meat (Anon., 1995e) and the meat is sold locally or to processing companies in Greenland. Hunters are obligated to use all of the edible parts of the catch and meat that is not used or sold must be given to the local community (Anon., 1995e).

##### *Regulation of use*

IWC quotas regulate minke whale hunting internationally. West and East Greenland are each given a yearly quota, which they distribute among the counties (Anon., 1995e). Only individuals with a professional hunting license can apply for a permit to hunt minke whales.

Vessels to be used in the hunt must be smaller than 70 feet and have a line or trawl winch. Only 50 calibre or larger harpoon guns can be used. A wounded whale that has not been killed must be put down as quickly as possible with shots in the head region using a harpoon shell or a minimum of a 7.62 (30.06) or 9 mm calibre rifle with a sharp-nosed bullet (full-mantel) (Anon., 1995e). If the minke whale catch is thought to be of great importance to the local community, permission may be given to conduct communal hunts. This requires the participation of at least five dinghies and that handheld harpoons and rifles of the above calibre are used (Anon., 1995e).

Minke whales can be hunted from the 1st of April to the 31st of December. Minke whales caught in "sassat" (ice entrapments) however, can be taken year round. When minke whales are accompanied by offspring, neither the female whale nor the young may be shot at or taken (Anon., 1995e). Minke whale kills and woundings have to be reported immediately to the resident county. In West Greenland all kills and woundings are subtracted from the county's quota, while only the number of successful kills are subtracted from the quota in East Greenland (Anon., 1992). The hunter with the permit is responsible for submitting information about the location of the hunt and the flensing of the whale and the whale's length, approximate weight, sex, etc. Certain types of information must also be submitted when whales are wounded (Anon., 1992).

Minke whales are listed in CITES Appendix II (table 14).

##### *Catch size*

The three-year quota for minke whale catch along West Greenland for 1995-97 totalled 465 whales, while in East Greenland it was 12 minke whales per year (Anon., 1997h). In 1996 168

minke whales were taken in West Greenland, of which 109 were taken with harpoons and 50 with rifles, one was killed illegally, four were wounded and lost and four were caught secondarily in nets (these are not subtracted from the quota). In the same year 12 minke whales were taken in East Greenland and none were wounded, lost or caught in nets (Anon., 1997h).

#### *Population status*

According to IWC, minke whales in Greenland comprise an independent population. It is likely that the minke whales by West Greenland are part of a larger population that has not been identified yet. Based on aerial counts, the number of minke whales along West Greenland in 1993 was described as being somewhere between 2400 and 16,900. It is not known whether minke whale abundance along West Greenland is increasing, constant or decreasing (Anon., 1995c). Minke whales along East Greenland formally belong to the central Atlantic (Icelandic) population, however, this relationship has not been scientifically documented. Icelandic counts in 1987 and 1989 totalled somewhere between 21,600 and 31,400 minke whales in the central Atlantic population. There is no separate estimate for Southeast Greenland and nothing is known about minke whale population tendencies in this area (Anon., 1995c). Since population boundaries are uncertain and estimates of population size are too imprecise it is not possible to determine if hunting pressure is influencing the population's status. However, it is believed that there presently is no need for additional management initiatives (Anon., 1995c).

#### **4.4.17. Fin whale (*Balaenoptera phusalus*)**

##### *Species distribution*

Fin whales (*Balaenoptera phusalus*) are found by West Greenland from Nunap Isua to Upernavik, both on banks and in coastal regions. By East Greenland they are primarily found beyond the pack ice belt (Anon., 1995c).

##### *Hunting method*

Fin whales are hunted with harpoon guns from vessels that are at least 30 feet long. After the kill, the whales are kept afloat with buoys and towed to a suitable flensing place on land. Fin whales are only hunted in West Greenland since there are no vessels with harpoon guns in East Greenland.

##### *Use of the species*

Fin whales are not hunted commercially in Greenland and the International Whaling Commission (IWC) defines its fin whale catch as "aboriginal/subsistence catch". It is illegal to commercially export fin whale meat (Anon., 1995e) and the meat is sold locally or to processing companies in Greenland. Hunters are obligated to use all of the edible parts of the catch and the meat that is not used or sold must be given to the local population (Anon., 1995e).

##### *Regulation of use*

IWC quotas regulate fin whale hunting internationally. West Greenland is given a yearly quota, which it distributes among the counties (Anon., 1995e). Only individuals with a professional hunting license can apply for a permit to hunt fin whales. To obtain a permit a vessel that is at least 36 feet long or two vessels of at least 30 feet each must be used per whale killed. The vessels have to have a harpoon gun and a line or trawl winch, as with minke whales. An extra harpoon shell must also be ready when hunting fin whales (Anon., 1995e).

It is prohibited to kill fin whales smaller than 15.2 m. When fin whales are accompanied by offspring, neither the female nor the young can be shot at or killed (Anon., 1995e). As with minke whales, fin whale kills and woundings and other types of information have to be reported immediately to the resident county (Anon., 1995e).

Fin whales are listed in CITES Appendix I (table 14).

### *Catch size*

From 1978 to 1993 the fin whale catch has been between 5 and 19 whales per year (Anon., 1995c). In 1995-97 the yearly quota was 19 fin whales (Anon., 1997h). This quota only encompasses successful hunts, i.e. wounded whales that are lost are not included in the quota. In 1996 19 fin whales were successfully hunted and one was lost (Anon., 1997h).

### *Population status*

According to IWC the fin whales by West Greenland comprise an independent population. Although this does not seem probable, the demarcation is maintained to be cautious in the population's management (Anon., 1995c). Based on aerial counts conducted in 1987 and 1988, the number of fin whales by West Greenland has been calculated to be between 520 and 2100. It is not known whether fin whale abundance by West Greenland is increasing, constant or decreasing. If Greenland's fin whales in fact are an independent population, which is unlikely, there is reason for concern over the current catch size (Anon., 1995c).

## **4.4.18. Greenland halibut (*Reinhardtius hippoglossoides*)**

### *Species distribution*

Greenland halibut (*Reinhardtius hippoglossoides*) are common in the waters surrounding Greenland by the west coast up to Smith Sound and by the east coast up to Ittoqqortoormiit (map 36). They are most frequently found on soft substrate at depths of 200 to 2000 m with a tendency for the larger fish to occupy the deepest water (Jensen, 1935; Jørgensen, 1997).

### *Fishing method*

Atlantic halibut fishing can be divided into two types of fishing, fishing in sheltered waters and fishing in open (unsheltered) waters. Maps 41 and 42 give an overview of where Greenland halibut were fished in 1995. Sheltered water fishing takes place along the entire west coast, with the greatest concentration by Illulissat and the regions around Uummannaq and Upernavik. Open water fishing is concentrated in the central part of the Davis Strait. On the east coast fishing occurs almost exclusively in open water and takes place from the Davis Strait southward.

Long-lines and sink seines are used for sheltered water fishing. During the winter dog sleds are driven onto the sea ice where the lines are put through a hole in the ice. A glider draws the line across the bottom and makes it possible to fish with up to 150 hooks per line. In areas with open (ice-free) water, the lines are put in from small dinghies and in recent years, increasingly from fishing vessels with an automatic line system. An automatic line system makes fishing less labour-intensive and because of this, several thousand hooks can be placed on the line. Cephalopods, strips of halibut, eelpouts (Zoarcidae) and capelins are used for bait. Net fishing was introduced in the middle of the 1980s. It has since then become somewhat established in open (unsheltered) water fishing. In 1996 net fishing comprised 25% of open water Greenland halibut fishing. Mostly trawl fishing, but also long-line fishing, is used in open (unsheltered) water fishing. Fish are caught at depths of 800 to 1600 m with large line fishing vessels and trawlers. Greenland halibut trawl fishing is generally illegal in Greenland's territorial waters, but in the past few years Greenland's Home Rule Government has granted exceptions to the ban.

### *Use of the species*

At one time Greenland halibut were an important component of everyday domestic life, for human consumption and as dog food. During the past 50 years major changes have taken place to make Greenland halibut exploitation more of a commercial venture. From 1950 to the 1970s salted Greenland halibut was exported and the species became increasingly more economically important. Today Greenland halibut ranks second, after pink shrimp, among the species of most economic importance to Greenland. It is of particular economic importance in Northwest Greenland (Smidt, 1989).

### *Regulation of use*

Currently there are no restrictions on the quantity of Greenland halibut that can be taken when fishing in sheltered waters. However, attempts at regulating the catch are continually made by, for example, limiting the types of implements used for fishing and establishing protected zones (Anon., 1996d; 1997j). A quota has been set for fishing in open (unsheltered) waters. The quota in West Greenland in 1997 was 5500 tons of fish: 2250 tons for Greenland, 550 tons for the EU, 150 tons for the Faeroe Islands, 1900 tons for Norway and 650 tons for Russia (Anon., 1997i). In East Greenland the quota for 1997 was 8100 tons: 1500 tons for Greenland, 4250 tons for the EU, 150 tons for the Faeroe Islands, 1700 tons for Norway and 500 tons for Russia (Anon., 1997i).

### *Catch size*

Historically there has been a shift in the exploitation of Greenland halibut. Earlier, sheltered water fishing was mainly a side occupation and a few fishermen or hunters typically switched between, for example, fishing for shrimp and Greenland halibut and hunting marine mammals. Now Greenland halibut fishing has become a main occupation while the other types of fishing and hunting in several places has become secondary. The total catch rose from 7000 tons in 1987 to 19,000 tons in 1996.

### *Population status*

Currently two important spawning areas are known for the Greenland halibut, one in the Davis Strait south of the submerged ridge between Greenland and Baffin Island (around 67° N) and one on the slopes of the continental shelf west of Iceland (Sigurdsson, 1980). From the spawning sites Greenland halibut fry are carried with the current up along Greenland's west coast. The banks southwest and west of Qeqertarsuaq are recognized as important maturing grounds for Greenland halibut fry (map 37). The populations in West Greenland's fjords originate from the Davis Strait spawning region (Jensen, 1935; Smidt, 1969). There are indications however, that part of the population in the southwestern fjords originates from the spawning sites west of Iceland (Riget & Boje, 1989; Boje, 1990). East Greenland's population is thought to originate exclusively from the Icelandic spawning region (Jensen, 1991).

The Greenland halibut population living in sheltered waters by West Greenland has gone from being a relatively unexploited resource to being intensively exploited. The area around Ilulissat, in particular, has experienced a drastic increase in fishing. The total fish take rose more than 340% from 1987 to 1996. The regions Uummannaq and Upernavik have also experienced a drastically increased amount of fishing (map 42). There are indications that the increase in fishing has caused a shift in the population towards smaller and fewer Greenland halibut, particularly in the area by Ilulissat, but also by Uummannaq (Bech *et al.*, 1996; Riget & Boje, 1987a; Boje, 1993). Marking studies in the fjords of Northwest Greenland have shown that the fish do not perform a spawn migration to spawning areas in the Davis Strait (Riget & Boje, 1978b; 1989). Fish in spawning condition are only observed sporadically in the fjords of Northwest Greenland (Jørgensen & Boje, 1994), suggesting that Greenland halibut populations in these fjords only contribute sporadically to recruitment. Therefore, a high degree of fishing in sheltered waters would probably not affect spawn biomass and thereby halibut recruitment.

Trawling is by far the most common type of fishing conducted in open (unsheltered) waters. When trawling, mostly small fish (< 60 cm) are caught and among these, the majority of females are not sexually mature. This means that fish are removed from the population before they have had a chance to reproduce. Since many things regarding Greenland halibut reproduction still are unclear, the relative effect of open water fishing on the total sheltered and open (unsheltered) water recruitment on the west coast is not known.

Open (unsheltered) water fishing by the east coast increased until 1989, but has since then stabilized at a relatively high level (1200 tons in 1996). Because of high fishing pressure, the spawning population today is thought to be historically low (Anon., 1997k).

#### *Unintended consequences of use*

Other deepwater fish are caught secondarily when trawling, of which primarily rockfish (Scorpaenidae) and grenadier (Macrouridae) species are of commercial interest (Jørgensen, 1995). In addition, quite a few Greenland halibut are caught that are under the minimum length (45 cm). The fishing industry most likely has an effect on benthic fauna in general since the trawl shovels, wire and net influence the sea bottom. However, the actual effect is unknown. Secondary catches occur with long-line fishing as well, but because of the greater selectiveness of hook fishing, the secondary catch is smaller than with net and trawl fishing (Jørgensen, 1995). There have been fears that lost sink seines continue to catch fish as so-called "ghost nets", but no evidence has been found to support this assumption (Bech & Kloster, 1994; Bech & Jeremiassen, 1995).

#### **4.4.19. Atlantic cod (*Gadus morhua*)**

##### *Species distribution*

Atlantic cod (*Gadus morhua*) occur on the west coast up to Qeqertarsuaq and on the east coast up to Tasiilaq. They are found from the coast down to about 600 m in depth, either along the bottom or pelagic. Atlantic cod were previously found on the fish banks of West Greenland. However, they have more or less disappeared from there and today only coastal Atlantic cod are found that spawn in the fjords.

##### *Fishing method*

The majority of Atlantic cod fishing occurs in sheltered waters in fjords. Cod complete seasonal spawning and foraging migrations in and out of the fjords and cod fishing in fjords is at its highest from the beginning of May to the end of August. During this time period, the cod are for the most part high in the water column and can be caught with pound nets (an attached trapping device used in shallow water along the coasts). About 80% of all fjord cod are caught with pound nets. During the remainder of the year, when the cod are further down in the water column, fishing is more sporadic and occurs particularly with seine nets (gillnets that are anchored to the bottom) and 'snelle' (two or more hooks embedded in a metallic fish that is moved up and down). Trawling is used in open (unsheltered) water cod fishing, but there has not been any significant open (unsheltered) water Atlantic cod fishing since 1992. Fishing has been restructured with the disappearance of cod in open waters, but small-time fishing vessel and dinghy fishermen have a hard time finding alternatives to cod fishing (GSK, 1991).

##### *Use of the species*

Cod are fished both commercially and for domestic use. Most cod are filleted and frozen or dried. A great deal of cod is also sold fresh at the local market. The roe is smoked or sold fresh. Discarded parts are used for making fishmeal and cod-liver oil.

##### *Regulation of use*

A collective quota of 83,000 tons per year for open (unsheltered) water bank Atlantic cod and sheltered water coastal Atlantic cod, has been negotiated with the EU. The quota has been set arbitrarily rather than based on biological advisories. The biological advisories suggest that all open water cod fishing be stopped until a significant increase in spawning biomass is documented and that the sheltered water population be protected by increasing the minimum allowable size of individuals caught and the prohibition of fishing in certain fjord regions (Anon., 1997l).

### *Catch size*

The size of the Atlantic cod catch by Greenland has decreased drastically in recent years. From 1990 to 1992, the catch fell from 130,000 tons to 17,104 tons. There has not been any directed fishing of cod in open (unsheltered) waters since 1992. The catch in sheltered waters has also decreased markedly from 5700 tons in 1992 to only 700 tons in 1996 (Anon., 1997I).

### *Population status*

Since the middle of the 1970s several small Atlantic cod populations in the fjords along the west coast and on occasion, cod larvae from the sea around Iceland, have been the foundation of cod fishing in Greenland. The previously important Greenlandic cod population on the banks has experienced decreasing recruitment since the beginning of the 1970s, and today has more or less disappeared. The immigration of large quantities of cod from Iceland has not occurred since the end of the 1980s. The declines in Greenland's cod populations should be viewed as a combination of several factors. Population analyses shown that the open water cod population on the banks collapsed in the middle of the 1970s due to over fishing (Anon., 1996e). At the same time, there are several indications that the climate has changed in the sea around Greenland and this has been a contributing factor keeping the cod from re-establishing themselves on the banks (Buch *et al.*, 1994). Climate changes may also have caused a change in the influx of cod larvae from Iceland. Fish of Icelandic origin have only contributed significantly to the annual fishery in Greenland twice since the beginning of the 1970s (Buch *et al.*, 1994). The decline in the sheltered water population has probably also resulted from heavy fishing and lack of new recruitment over the course of several consecutive years (Engelstoft, 1997).

### *Unintended consequences of use*

Cod fishing does not have any direct impact on any other species since pound nets are very selective and rarely result in a secondary catch. In addition, under-sized fish can be released from the trap alive. Gillnets can have small secondary catches of sculpins (Cottidae), crabs and Greenland halibut, but only in limited numbers. It may be a problem that many seine nets and pound nets are lost in important fishing areas and continue to catch fish by "ghost fishing". Counties periodically dredge certain areas to clear away lost fishing implements.

## **4.4.20. Rockfish (*Sebastes spp.*)**

### *Species distributions*

Both ocean perch (*Sebastes marinus*) and deepwater redfish (*S. mentella*), collectively termed rockfish, are common towards the north to Qeqertarsuaq and Tasiilaq, respectively. Ocean perch are benthic, while deepwater redfish occur as an oceanic and a benthic type.

### *Fishing method*

There has long been foreign interest in fishing rockfish in the waters surrounding Greenland. In fact, West German, Russian and Icelandic fishermen in particular, have fished extensively for rockfish in both West and East Greenland since the middle of the 1950s. In the 1980s the fishery was reduced to East Greenland because of a decreasing catch size. Rockfish are fished in East Greenland using mid water trawl and bottom trawl. The fishery is divided into a traditional trawl for the two benthic species *Sebastes marinus* and deep sea *S. mentella* and a mid water trawl for oceanic *S. mentella*, which lives in the free water masses.

### *Use of the species*

Rockfish are most often sold as frozen fillets. However, quite a few are sold fresh, and others are salted or smoked. The liver is rich in oils and vitamins but is seldom used.

### *Regulation of use*

All three rockfish populations are fished by quota on the basis of recommendations given by the International Council for the Exploration of the Sea (ICES) and according to various fish-

ing agreements between Iceland, Russia, the EU and Greenland. Rockfish maturing grounds are found by West Greenland and East Greenland. In order to protect rockfish fry, Greenland's Home Rule Government, following recommendations by ICES, established an area by East Greenland where any form of bottom trawling for rockfish is prohibited. This measure is supposed to prevent a secondary catch of rockfish fry when shrimp fishing.

#### *Catch size*

The total catch of ocean perch within Greenland's 200-nautical mile boarder was around 15,000-30,000 tons per year until 1983. During the 1980s the catch was reduced to a level somewhere around 1500-4000 tons. In 1995 German trawlers discontinued fishing by East Greenland. This has resulted in a drastic decrease in the catch to only 50 tons per year, which is primarily taken as secondary catch in the shrimp fishery. ICES estimates the present ocean perch population to be very low and perhaps below the biologically critical level. Continued fishing at the current level will not be sustainable. It is recommended that the total fishing pressure on the population should be reduced by 25% relative to current fishing levels (Anon., 1997I).

At the beginning of the 1980s the annual benthic deepwater redfish catch was between 10,000 and 15,000 tons, but in 1987-92 it fell to about 6000 tons. Only very small deepwater redfish were caught in 1994. The 1995 catch of about 1000 tons was the to date smallest catch and associated with the fact that Germany had discontinued fishing. It is not possible to evaluate the status of benthic deepwater redfish from a historic perspective, but there has been a drastic decline in catch rates (catch per effort) and average fish size over the past five years, and ICES recommends that the total fishing pressure should be reduced by 25% relative to current fishing levels (Anon., 1997I).

Fishing for oceanic deepwater redfish started in 1981/1982 with mid water trawling and quickly rose to more than 80,000 tons. In 1991 the catch size was down to 17,000 tons and in 1995 rose again to 40,000 tons. The oceanic deepwater redfish population is believed to be above the biologically critical level. ICES estimates that a catch of 130,000 tons per year, which is the current level, is sustainable (Anon., 1997I).

There is great uncertainty regarding rockfish systematics and therefore, disagreement about species and type grouping. Ocean perch (*S. marinus*) and deepwater redfish (*S. mentella*) can be discriminated between as adults but not as juveniles, and the two types of deepwater redfish (deep sea and oceanic) cannot be discriminated between. These conditions make it difficult to conduct population statistics on the rockfish, but it is estimated that the rockfish fishery and the secondary catch of rockfish in the shrimp fishery are the major cause of the decline of the benthic rockfish (Anon., 1997I; Engelstoft, 1996).

#### *Unintended consequences of use*

Rockfish fishing is very 'clean'. The secondary catch with both bottom trawl and mid water trawl is minimal. Bottom trawling will inevitably have an effect on the benthic community, but this effect has not been studied. When fishing for oceanic rockfish, 50 to 100 trawlers may be gathered within a small marine area. It is likely that such a concentration of ships creates quite a bit of local pollution in terms of noise and the leaking of oil.

### **4.4.21. Atlantic salmon (*Salmo salar*)**

#### *Species distribution*

Atlantic salmon (*Salmo salar*) occur along Greenland's coast from August to about November on foraging migrations from the American and European continents. Their distribution varies greatly from year-to-year depending on the ocean surface water's climate. The salmon's northernmost boundary normally occurs by Aasiaat on the west coast and Ittoqqortoormiit on the east coast. In Greenland, Atlantic salmon only breed by Kapisillit in the fjord network by Nuuk.

### *Fishing method*

Salmon fishing occurs from August to November. Fishing activity is greatest south of Qeqertarsuaq on the west coast. In addition, there is also a limited amount of fishing by Tasiilaq. Fishing occurs close to the coast in small vessels. Stationary nets are used in the commercial fishery and hooks and fishing poles, stationary or drift nets are used for non-commercial fishing.

### *Use of the species*

Salmon are exploited commercially, sold locally and used in private households. Only individuals with a professional fishing license are permitted to sell salmon (Anon., 1997n). Salmon is sold as smoked or fresh products.

### *Regulation of use*

Salmon have been fished by quota since 1976. Along West Greenland salmon must be fished within 40 nautical miles of the baseline and on the east coast, within 12 nautical miles. Fishing is only permitted within a set period, from August to November. To obtain a permit to fish salmon professionally, the applicant must own salmon nets and a vessel smaller than 42 feet to be used for fishing. Professional fishing can be done only with hooks or nets with a mesh size of 140 mm. All of Greenland's permanent residents are allowed to fish for salmon for private use. It can only be done from vessels up to 42 feet long. A hook and fishing rod and one stationary net or one drift net per vessel may be used, and the nets have to be checked within 24 hours. Nets must be marked with the owner's name or vessel number. In sport fishing for tourists, only hooks and fishing rods can be used (Anon., 1997m). All salmon catches have to be reported to Greenland's Fishing Permit Commission (Anon., 1997n).

### *Catch size*

The salmon fishery was originally comprised of limited sheltered water fishing, but since the beginning of the 1960s has grown to include Norwegian, Faeroese and Danish fishermen by West Greenland (Smidt, 1989). The salmon fishery peaked at the beginning of the 1970s with over 2500 tons and has since fallen to a very low level (Anon., 1997o). In 1996 only 92 tons were caught by West Greenland (Anon., 1997o).

### *Population status*

The salmon occurring by Greenland are made up of about 65% originating from North America, 35% from Europe and very few from Greenland (Anon., 1997o). The populations in both the western and eastern Atlantic Ocean have declined noticeably within the past two decades (Anon., 1997o). This means that in spite of some degree of positive development in recent years, population numbers in all regions are unacceptably low, relative to previous levels (Anon., 1997o). It seems that the population's poor condition in its home waters is the result of not only human induced conditions such as regulation of floods, pollution and too high a fishing pressure, but also of an unfavourable development in climate conditions in marine areas where juvenile salmon mature (Anon., 1997o).

The International Council for the Exploration of the Sea (ICES) collects the results of salmon studies throughout the North Atlantic and publishes an annual report on the status of salmon populations and recommendations for exploitation in the various regions. These reports are the basis for the quotas and types of regulations that are adopted and distributed by the North Atlantic Salmon Conservation Organization (NASCO). In 1996 however, an agreement could not be reached on one of ICES's recommendations regarding the closing of ocean fishing by Greenland and Canada, which would make it possible for the spawning population to recover. Instead, Greenland had to set its own quota, which was 174 tons in 1996. In 1997 NASCO agreed that there should be some fishery in Greenland even though the biological advisory was for no fishing whatsoever. As such, the quota in 1997 was 57 tons.

Atlantic salmon exploitation in Greenland probably only has a marginal effect on the resident population (Anon., 1997o). However, "salmon producing countries" are very aware that there should be a limited degree of exploitation until the populations have recovered to a much higher level than where they currently are.

#### *Unintended consequences of use*

Previously a large number of thick-billed murres (*Uria lomvia*) drowned in salmon nets. The number of birds caught in nets decreased sharply when the foreign fisheries by Greenland shut down in 1976 (Kampp *et al.*, 1994).

#### **4.4.22. Arctic char (*Salvelinus alpinus*)**

##### *Species distribution*

Arctic char (*Salvelinus alpinus*) have the northernmost distribution of any freshwater fish and are found throughout Greenland in lakes, streams and near the coasts (Muus, 1990; Nielsen & Bertelsen, 1992). Arctic char do not migrate long distances out to sea, but stay by the coast close to the stream they migrated from. Some Arctic char populations are stationary and spend their entire lives in fresh water without migrating to the sea (Muus, 1990).

##### *Fishing method*

Primarily migrating Arctic char populations are fished. Either a fishing rod or a net is used for fishing. Arctic char are fished in all inhabited regions in Greenland, usually from June to September. Fishing is primarily for private use, but there is also a small commercial char fishery (Smidt, 1989).

##### *Use of the species*

The Arctic char is an important species in private households. Both the private and commercial catch is either frozen or smoked.

##### *Regulation of use*

Arctic char can only be fished with hooks for angling, landing nets and nets with a mesh size of 100 mm when stretched. The net must be a maximum of 30 meters long and marked with the owner's name, the name of the boat or vessel number. When the fishing site is left, the net must be hauled in no matter how long it has been left in the water. It is illegal to fish for Arctic char with nets in streams and their associated pools. In addition, it is prohibited to put up nets in lakes within 100 m of an in- or outflow stream. Arctic char fishing with nets is only permitted from the 15th of June to and including the 25th of September (Anon., 1997q).

Every five years local authorities must make a list of potentially productive char streams that are believed to be most threatened by over-exploitation. The list is used as a basis for the five-year protection of one or more of each county's areas with Arctic char populations. However, the county can give permission for fishing in protected areas with handlines and fishing rods to maintain the traditional, recreational value of Arctic char areas (Anon., 1997q).

##### *Population status*

The majority of Arctic char migrate back to the stream where they hatched. This means that the species occurs in local populations that have a limited amount of mixing with other populations and that the within species genetic diversity probably is rather high. It is therefore impossible to give an overview of the status of the many local populations. Individual populations cannot tolerate a high degree of fishing since Arctic char populations in each stream are small and the species has a slow growth rate (Smidt, 1989; Muus 1990). Local protection in each county is supposed to prevent over-fishing of Arctic char in individual streams and will secondarily preserve genetic diversity within the species.

#### *Catch size*

There is no figure for the number of Arctic char caught annually since the majority are for private use. However, there is no doubt that the amount of exploitation has increased with the increase in the number of private vessels and their activity radius (Nielsen, pers. comm.). Only a small portion of the catch is commercial. In 1996 the commercial trade of Arctic char was about 43 tons and in 1997 79 tons were sold by the end of August (Anon., 1997p).

#### *Unintended consequences of use*

In cases where the net is left without supervision, in spite of prohibitions against this, birds are caught in nets and drown. Birds and other animals can also get caught in nets left on land.

### **4.4.23. Pink shrimp (*Pandalus borealis*)**

#### *Species distribution*

Pink shrimp (*Pandalus borealis*) are found throughout the North Atlantic. They thrive in water temperatures between 0 and 5° C and occur on soft or sandy substrates at depths between 50 and 500 m (Shumway *et al.*, 1985). In Greenland, pink shrimp occur along the entire coast and the largest concentrations are found at depths of 200 to 450 m along the southern part of the east coast, as well as along the west coast and in Qeqertarsuup Tunua.

#### *Fishing method*

Pink shrimp fishing occurs from two types of vessels: small fishing vessels that fish along the coast, in the fjords and in Qeqertarsuup Tunua and large trawlers that fish at sea. Shrimp are fished with bottom trawl, where the trawl shovels spread a net bag out after the boat. The net bag is equipped with a heavy boom that keeps the net in contact with the bottom. Trawls used for shrimp fishing are relatively tall compared to trawls used for fish. On the big trawlers, the trawl is about 20 m high and 30 m wide. It is almost exclusively Greenlanders that fish for shrimp in the waters surrounding Greenland.

#### *Use of the species*

The pink shrimp is the species of most economic importance to Greenland. The shrimp fishery creates many jobs in the fishery itself and in factories on land. After preliminary processing, most of the catch is exported overseas.

#### *Regulation of use*

Shrimp fishing with trawlers has been set by quotas since 1977, and at the end of 1996 quota regulations were established for smaller fishing vessels as well. The fishery quotas can be exchanged, but with limits on quota sales between the fishing vessel fleet and the trawler fleet. The total quota for 1997 was 64,600 tons on the west coast and 4000 tons on the east coast for Greenlandic vessels. Quota regulations of the trawler fishery and an improvement of trawler performance have resulted in a reduction in the number of trawlers in the Greenlandic shrimp fishery. In 1992 there were 40 trawlers, 27 of which were left in 1996 (Anon., 1996f). A reduction in the number of ships in the fishing vessel fleet will probably also occur with the introduction of quota regulations.

The fishery is also regulated with limitations on the implements used. The use of a trawl with a mesh size less than 40 mm is prohibited. Finally, an area of the east coast is closed to shrimp fishing to protect rockfish fry.

#### *Catch size*

Until the beginning of the 1970s shrimp fishing by West Greenland has occurred in sheltered waters with catch sizes under 10,000 tons. With the development of the open (unsheltered) water shrimp fishery the catch size rose to 43,000 tons in 1976 and increased until 1992 where the total catch was 80,000 tons. In 1996 the catch fell to about 67,000 tons (Hvingel *et al.*, 1997).

Shrimp fishing by East Greenland started in 1978 and rose sharply from a catch of 4000 tons in 1983 to 11,000 tons in 1988. The catch has since been declining and in 1995 was at 4000 tons (Hvingel *et al.*, 1996). The geographical distribution of the fishery and the size of the catches in 1995 are shown on map 43.

#### *Population status*

Pink shrimp in the waters surrounding Greenland are viewed as belonging to two separate populations: an East Greenlandic population that is shared with Iceland and a West Greenlandic population that is shared with Canada. The separation of the two populations occurs at 46° W south of Nunap Isua. The division is based more on administrative and practical reasons than actual biological information. It reflects the dividing line between international management organizations, the Northwest Atlantic Fisheries Organization (NAFO) and the International Council for the Exploration of the Sea (ICES).

The population's status is evaluated annually by the scientific committee under NAFO. When the population on the west coast started to show signs of decline in the beginning of the 1990s, Greenland's Home Rule Government decreased quotas for large trawlers. In comparison to 1994, the quotas were reduced by 5% in 1995 and another 5% in 1996. With the population evaluation in November 1997, the largest recommended catch was decreased to 55,000 tons on the west coast and 5000 tons on the east coast (Anon., 1997r).

The population on the west coast was a bit smaller throughout the 1990s than it was in the 1980s and in recent years, a further decline has been observed. With the establishment of the recommended catch, it was emphasized that the most recent catch level was indicative of the biomass and in order to change this development and protect future recruitment, the catch should be reduced to 55,000 tons.

The evaluation of the population's status on the east coast has been confounded in recent years by changes in fishing patterns. Before 1993 fishing occurred exclusively on Dohrn Banke north of 65° N, now a large portion of the fishery has spread southward to new fishing areas. It has therefore not been possible to ascertain whether there have been any changes in the population's condition.

#### *Unintended consequences of use*

Shrimp fishing uses relatively small-meshed bottom trawl, which therefore gives a large secondary catch of undersized halibut, rockfish and polar cod (*Boreogadus saida*). The size of the secondary catch relative to the total catch depends on the volume of individual fish species. In recent years, secondary catches have not been a big problem, perhaps because many benthic fish have declined drastically and only have a small annual productivity in shrimp areas. An attempt is being made to reduce the secondary catch with the introduction of a mandatory sorting grate in the shrimp trawl. Trawling itself affects benthic fauna since it can destroy attached species and the stirred up sediment can affect filter feeders. For slow-growing species this may harm the population, but this relationship has not been investigated. Finally, the mechanical effects of the trawl on the soft muddy substrate change both inorganic and organic conversion rates. It is not known how large the changes may be or to what degree benthic fauna are affected.

#### **4.4.24. Snow crab (*Chionoecetes opilio*)**

##### *Species distribution*

Snow crabs (*Chionoecetes opilio*) occur along Greenland's west coast. The species has not been documented west of Nunap Isua. It is typically found at water temperatures ranging from -1° to 3° C. The depth at which snow crabs occur and the type of substrate they are found on depends on the time of year and the size of the individual crab. Small crabs and females are primarily found at shallower depths and males at greater depths. The crabs generally seek

out shallower depths in the spring in association with mating. They are found on various types of substrate. Studies suggest that small crabs are most frequently found on sandy/muddy substrates and large crabs are often found on rocky/muddy substrates (Andersen, 1993; Burmeister & Mathiassen, 1996).

#### *Fishing method*

The snow crab fishery started in 1992 and presently the crabs are primarily fished in sheltered waters (map 44). In 1996 snow crabs were fished from Nuuk to Qeqertarsuup Tunua (Burmeister, 1997b) and in 1997 in sheltered waters by Sisimiut and in Qeqertarsuup Tunua. Crabs can be fished year round in ice-free regions. The vessels used in the commercial snow crab fishery are 42 foot long or smaller. Crabs are caught in conical or square crab pots that have various types of bait such as a combination of uvak (*Gadus ogac*) and squid. Crab pots are rigged to a line and the number of pots used varies from a few to about 50. When placed in the water, crab pots sink to the bottom where they are left for a six to more than 24-hour period. Crab fishing is commercial and exclusively based on male crabs that have a carapace longer than 90 mm. The crabs have to be sold to processing companies while they are alive. This limits the fishery in winter months because frost causes the crabs to drop their legs when they lie on the deck.

#### *Use of the species*

The crabs are sold to factories. Preliminary processing consists of boiling or freezing. The meat from the claws and legs is eaten.

#### *Regulation of use*

A permit is required to fish for crabs. Presently the only restriction in the crab fishery is that the crabs have to have a carapace length of at least 90 mm, which protects the females from being fished directly. In addition, male and female crabs smaller than the minimum size must be re-released if possible (Anon., 1995f).

#### *Catch size*

Snow crab fishing started in 1992 as an experimental fishery in the area by Qeqertarsuaq and since spread to Aasiaat, Sisimiut and Qeqertarsuup Tunua. Actual commercial exploitation started in 1995/1996. The total crab trade rose from 3 tons in 1992 to 998 tons in 1995. In 1996 the total catch of crabs along the west coast was reduced by 18% to 817 tons. The decline from 1995 to 1996 was partly caused by a reduction in fishing around Nuuk, where the catch was reduced by 86%, and partly by a shortening of the crab-fishing season. Since 1995 crab fishing has been most intense in the area around Sisimiut and in 1996 the amount caught in this area made up 51% of the total catch along the west coast (Burmeister, 1997b).

In 1996 the total catch was distributed as follows: 32 tons by Nuuk; 419 tons by Sisimiut, 112 tons by Aasiaat and 176 tons by Qeqertarsuaq.

#### *Population status*

Studies focusing on population evaluations and making recommendations regarding snow crabs started in Greenland in 1991. Up to 1997 biological studies were carried out in sheltered water regions by Paamiut, Nuuk, Maniitsoq, Sisimiut, Kangaatsiaq and Qeqertarsuup Tunua. The total biomass of snow crabs of commercial interest has been calculated to be 1900 tons by Kangaatsiaq and 2000 tons by Paamiut (Burmeister, 1997a), 460 tons by Nuuk (Andersen, 1992), 800 tons in sheltered water regions, 1660 tons in a limited open (unsheltered) water area by Sisimiut, 5900 tons by Qeqertarsuup Tunua and 1270 tons by Maniitsoq (Burmeister, 1997a; Burmeister, 1997c).

On the basis of the estimated existing biomass in each of the above mentioned regions and with an exploitation of 50% of the biomass (crabs with a carapace length greater than 90 mm)

in Paamiut, Nuuk, Maniitsoq and Qeqertarsuup Tunua, the total recommended catch size has been calculated to 990 tons by Paamiut, 230 tons by Nuuk, 630 tons by Maniitsoq, 940 tons by Kangaatsiaq and 2940 tons in Qeqertarsuup Tunua. Based on the documented reduction of biomass in the sheltered water area by Sisimiut in 1997, it was recommended that the catch be set to 35% of the biomass, which is equivalent to 280 tons, and with the exploitation of 50% of the biomass in the open (unsheltered) water region, 830 tons can be caught (Burmeister, 1997a; Burmeister, 1997c).

The largest recommended catch size is given separately for the various localities since the crabs do not migrate over long distances. A total allowable catch (TAC) for the entire west coast could result in individual areas being over fished. Population evaluation of the snow crab is rather new and it is too early to determine if the population along the west coast is stable, increasing or decreasing because of a lack of data. It is also too early to evaluate the potential effects of commercial fishing on the snow crab population. Around the period of ecdysis the crabs are soft and of little commercial interest. Currently there is no scientific documentation on the timing and length of the period in which the number of soft crabs dominate in Greenland. The survival rate of re-released soft crabs is very low and closing the fishery around the period of ecdysis would prevent an unnecessary reduction in the population. However, this requires that the timing and length of ecdysis are determined.

#### *Unintended consequences of use*

There are no problems with secondary catch of other species in the commercial snow crab fishery and the use of crab pots does not have a negative effect on habitat.

#### **4.4.25. Iceland scallop (*Chlamys islandica*)**

##### *Species distribution*

Iceland scallops (*Chlamys islandica*) are common along Greenland's west coast up to Qaanaq. On the east coast, they occur sporadically in the inner part of Kejser Franz Josephs Fjord and the southern part of Kong Frederik VI Coast. Iceland scallops occur at depths of 20 to 80 m. They thrive primarily on hard substrates, but are also found on substrates with sand, gravel, rock and occasionally clay. The scallops are attached to the substrate, which makes it possible for them to live in areas with very strong currents.

##### *Fishing method*

Iceland scallops are fished with medium-sized 100-200 BRT fishing vessels. They are fished with a scraping tool consisting of a powerful iron frame with a mat of iron rings. The scraping tool can weigh several tons. The scallops are fished along West Greenland in six primary areas: Nuuk; Attu south of Kangaatsiaq; the area south of Kangerluk; the area north of Akullit; Aqajarua and Upernavik Kujalleq. They are also sporadically fished in areas by Qaportoq, Sisimiut and north of Upernavik Kujalleq (map 45). Ice conditions off West Greenland influence fishery distribution. Around Nuuk scallops are fished until May and it is only in this period that all ships fish in the same area. The fishing boats move northward from Nuuk as the ice disappears and the Nuuk quota is used up. The remaining areas are fished from May to December without any set pattern (GFLK).

##### *Use of the species*

The adductor muscles and gonads of the Iceland scallop are used. They are frozen while they are fresh and the majority of the production is exported. The export is primarily to France and the United States.

##### *Regulation of use*

The Iceland scallop fishery is based on permits and since the middle of the 1980s permits have been given to 5-6 boats. In addition, three of the largest scallop areas by Nuuk, Attu and Aqajarua have a quota. There are no regulations on the catch size at the remaining sites.

### *Catch size*

The Iceland scallop fishery has been stable for a long time with annual catches of around 2000 tons. However, a drop in the price of Iceland scallops in traditional export countries made the market hit bottom at the beginning of 1996 and scallop fishing stopped completely. The price has risen a bit since then and the fishery has slowly started up again. Currently three boats fish for scallops, but only in the Nuuk area. In 1996 the catch was 1374 tons (GFLK).

### *Population status*

The Iceland scallop resource was studied and measured in 1988 (Pedersen, 1988). On the basis of this very extensive study, quotas were recommended for each site. In most years quotas have been higher than the ones recommended. Sites without a quota are new Iceland scallop regions that fishermen have discovered since the study in 1988. In 1994 the Nuuk site was re-evaluated. The population status showed the biomass had been halved in the years that had passed (Engelstoft, 1994). The remaining sites have not been studied since 1988.

Iceland scallops make up a relatively small resource distributed over a large area and there are no funds for conducting annual studies. It is therefore difficult to determine if exploitation of the species is sustainable. In addition, there are several areas of Iceland scallop biology that have not been investigated. For example, it is not known how often they spawn. The fishermen's logbooks show a decreasing catch rate (catch per effort) in all areas since the beginning of the fishery. There are therefore indications that the population has been over-fished.

### *Unintended consequences of use*

Various studies have been completed on the effect of scallop scraping on the sea floor. Fishing with scallop scrapers can cause large-scale unevenness on the sea floor, lift large pebbles from the sediment and presumably damage the epifauna. Intensive scallop fishing during strong tidal currents leads to an upwhirling of sediment (Caddy, 1973). This can have a negative impact on scallops as well as other sedentary shellfish since large amounts of clay or mud (particulate inorganic matter) can clog their gills and prevent the absorption of food and oxygen (Vahl, 1980). The scallop fishery has possibly contributed to the decline in the number of moulting king eiders (*Somateria spectabilis*) in Aqajarua. The fishery may disturb the birds in a vulnerable period and destroy the benthic fauna that they feed on (Frimer, 1993; 1995b).

## **4.5. Conclusion**

As is apparent from the previous chapters, the current status of biodiversity in Greenland is a product of a natural development and 1000 years of human exploitation of biological resources.

In conclusion, it can be stated that Greenland is extremely rich in natural areas, which in large parts of the country are untouched. The reason for this is, among other things, that the human population is not very dense and is concentrated in cities and settlements, and space requiring occupations such as farming are only present to a small degree. This means that Greenland, in contrast to many other countries, at present only has a few problems concerning the protection of conservation-worthy and rare environments.

An analysis of which ecoregions still need legislative protection in accordance with CPAN shows that only a few areas in the Low Arctic and Subarctic are protected. As indicated in section 4.3, there are four types of environments that should receive better legislative protection to ensure the occurrence of biodiversity in these biotypes in the future. In addition,

several rare plant species that mainly occur outside of protected areas should be protected with better legislation.

Greenland's problems related to biodiversity preservation are mainly in the direct exploitation of species by hunting and fishing.

In a review of Greenland's biological resources prepared by the Greenland Institute of Natural Resources (Grønlands Naturinstitut) in 2000, 39 wild animal species are mentioned as essential from an exploitation viewpoint (Anon., 2000). In section 4.4, the use and status of 25 of these species has been described. The use of ten of the species can be described as non-sustainable, but the causes of this over-exploitation have been identified with great confidence and it should be relatively easy for biological advisors to come up with concrete suggestions for how these resources should be managed. However, it is political decisions that have the final say in how biological resources are managed and political decisions on this topic are difficult to make in a country where hunting and fishing play an important role, both economically and culturally. This does not change the fact that in the coming years, Greenland must secure its biodiversity for the future at the political and legislative level.

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## 6. *Appendix*

