Monitoring large herbivore effects on vegetation in Greenland

- Workshop report

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- Workshop report

by

Arild Landa (ed.)

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Summary

Greenland Institute of Natural Resources (GN) has established an extensive network with expertise on large ungulate research and management. Objectives of the network include the enhancement of the research quality and competence at GN as well as the development of monitoring protocols, research programs and sustainable management plans for large ungulates in Greenland. Besides the importance of building a net-work group, another important task is to seek co-ordination and collaboration with international research groups with project interests within Greenland.

In parallel with comprehensive research on monitoring techniques and ungulate ecology, the institute has arranged two international workshops on caribou and muskoxen. The first workshop was about the establishment of goals for managing caribou and muskoxen in Greenland, whereas the present delt with the methods needed to monitor ungulate populations and vegetation. The present workshop gathered researchers and representatives from GN, The Home rule Governments' Directorate for Fishery, Hunting and Villages, experts from the Nordic countries, USA, Scotland and France. The workshop covered a background session on ungulates and grazing as well as a session on mapping the different monitoring and research tools available. Relevant questions on future monitoring and future research plans within Greenland were also addressed.

The workshop recommended that future monitoring should be built so that gathered material are processed and available for translation into management advice in a fast and efficient way. Several questions needs to be addressed. How is this herbivore plant balance and how can we be able to predict when populations growing too large and what densities can be within the different areas? A number of rapid habitat assessments to address sustainability questions in the short term, as well as building up a database in the long term are necessary. As a first step the refinement of the existing feedback system from the hunters should be manifested in simpler and clearer forms as well as expanding/developing the cooperation with locals to carry out simple monitoring procedures on vegetation and the density of animals. On a longer term the institutes' research and monitoring program should be co-ordinated and carried out in co-operation with the other relevant research interests from abroad.

The workshop and net work building is finaced by the Nordic Council (NARP Programme) and GN.

Eqikkaaneq

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Sammenfatning

Grønlands Naturinstitut har etableret et omfattende netværk vedrørende arbejdet med rensdyr og moskusokser i Grønland. Formålet er blandt andet at øge den faglige kompetence ved Naturinstituttet angående mere effektive undersøgelser og overvågning af rensdyr og moskusokser, samt at danne et fagligt netværk til støtte for det fremtidige arbejde. Arbejdet omfatter opbygning af et overvågningsprogram for vegetation, rensdyr og moskusokser, samt at koordinere og samarbejde med internationale forskergrupper i gennemførelsen af projekter i Grønland.

Parallelt med et omfattende forskningsarbejde i Naturinstituttets regi er der indtil nu afholdt to internationale workshops i relation til arbejde med rensdyr og moskusokser i Grønland. Den første workshop omhandlede fastsættelse af mål for forvaltningen af rensdyr og moskusokser i Grønland. Den anden, som afrapporteres her, omhandlede metoder til at vurdere og overvåge bestande af rensdyr og moskusokser samt vegetation i Grønland.

Denne workshop samlede repræsentanter fra Naturinstituttet, Direktoratet for Fiskeri, Fangst og Bygder samt eksperter fra de nordiske lande, USA, Skotland og Frankrig. Programmet for workshoppen omfattede bl.a. en baggrundssession om klovdyr og græsning såvel som en kortlægning af de forskellige overvågnings- og forskningsværktøjer, der er tilgængelige. Endvidere blev spørgsmål vedrørende overvågning og fremtidig forskning på klovdyr i Grønland præsenteret og diskuteret.

Workshopen anbefalede at fremtidig overvågning udformes på en måde, så indsamlet materiale hurtigt og effektivt kan omsættes i rådgivning til forvaltningen. Endvidere er det vigtigt at finde balancen mellem vegetation og klovdyr. Hvordan kan vi forudse hvornår bestandene bliver for store for græsningsunderlaget, og hvor mange dyr kan de forskellige områder bære? Såfremt

man skal opfange ændringer i antallet af rensdyr, moskusokser og deres fødegrundlag, blev det blandt andet anbefalet at fangsttilbagemeldingerne for fremtiden skal være mere simple og ledsaget af en bedre forklaring. Derudover må lokale kontaktpersoner i større grad indgå i arbejdet, således at disse personer kan udføre simpel overvågning af vegetationen og antallet af dyr. På længere sigt bør Naturinstituttet søge samarbejde med udenlandske forskningsgrupper der har projektinteresser i Grønland om at videreudvikle overvågningsprogrammet og forskningen vedrørende rensdyr, moskusokser og vegetation.

Dannelsen af det lokale og internationale netværkssamarbejde er finansieret af Nordisk Ministerråd og Grønlands Naturinstitut.

Preface

This NARP – network project, funded by the Nordic Council, is part of a dynamic process to improve the knowledge foundation for the yearly harvest recommendations, and thus promote sound and sustainable management of caribou and muskoxen in Greenland.

Although the Greenland Institute of Natural Resources (GN) is the largest research institute in Greenland, it is still relatively small with a scientific staff of approximately 20 persons. GN was established in 1995 to provide the Home Rule Government with scientific advice for the sustainable use of natural resources, among them caribou and muskoxen. The institute is expected, however, to cover a wide range of disciplines, and species, as well as vast areas on and around the worlds' largest island. It is therefore absolutely necessary to seek partners and form alliances with universities and other research institutes to achieve the scientific expertise needed to build knowledge and fulfil obligations.

The scientific study of west Greenland caribou and muskoxen is still in its infancy. Although several studies occurred in the past, there was previously no systematic or holistic approach to achieve information relevant to harvest management.

Since 1996 GN has carried out two primary and a few secondary projects on large herbivores. The first primary project was: "The interaction among caribou, vegetation and human activities in West Greenland", which aimed at improving the understanding of caribou populations on the west coast of Greenland. In 1999 the second primary project began: "Establishing a system for monitoring caribou and muskoxen in Greenland", which focused on monitoring techniques and obtaining current estimates of caribou and muskox abundance in west Greenland.

Other research institutions and universities abroad are conducting or planning related projects in Greenland. The purpose of this workshop, "Monitoring effects of large herbivore grazing on vegetation", was to gather key players and explore the possibilities for future cooperation on vegetation and herbivore research and monitoring projects. Establishing collaboration networks with several leading institutions will ultimately provide better scientific advice to the Home Rule Government for caribou and muskoxen management.

Arild Landa
Project coordinator
Nuuk, Greenland

Contents

About the NARP-network project

Harvesting caribou (*Rangifer tarandus groenlandicus*) and muskoxen (*Ovibos moschatus*) is both an economically and culturally important activity for the inhabitants of Greenland. However, there is much uncertainty concerning present status, ecology and management of caribou and muskoxen in Greenland.

Our current goal is to build a network group with expertise on large ungulate research and management, drawing from institutes in Greenland, Nunavut, Denmark, Norway and other relevant institutes.

Objectives for the network includes:

1. Enhance the Greenland Institute of Natural Resources' research quality and competence by building co-operation with large ungulate research groups from the Nordic and other relevant countries.
2. Develop monitoring protocols, research programs and sustainable management plans for large ungulates on Greenland.
3. Build a net-work group on muskox and caribou/reindeer monitoring/research and management.

Concrete objectives for this workshop:

1. Share experiences on vegetation & herbivore monitoring and research among northern countries
2. Develop recommendations for a methodology and project design suitable for application in Greenland.
3. Generate a better understanding of the role large herbivores play in vegetation dynamics and ecosystem processes, and be achievable under the field constraints that Greenland's nature imposes.

Network outputs:

- increased scientific competence at Greenland Institute of Natural Resources
- establishment of a net-work group of mutual benefit to each other and future research on wild Arctic ungulates in Greenland
- establishment of monitoring programs in Greenland for caribou and muskoxen
- recommendations for future research programs on caribou and muskoxen within the Nordic countries
- recommendations for increased local participation in caribou and muskox monitoring in Greenland.

Background

The Greenland Institute of Natural Resources (GNI) was established in 1995 and is the Home Rule government's centre for biological research. GNI is responsible for achieving scientific knowledge on the natural resources of Greenland, among them caribou and muskoxen. GNI is expected to provide valid recommendations to the Home Rule government for sound harvest management of these large ungulates. The best way to achieve an optimal and sustainable harvest of these resources is much debated, mainly because of a lack of clear goals, lack of information on species ecology and previous monitoring techniques. There is therefore a need to increase GNI's competence in establishing effective (1) research, (2) monitoring and (3) management protocols. To achieve these goals, we proposed the building of a network group among researchers from Nordic countries with expertise in large ungulate research and management. Furthermore, this should also promote increased exchange of information and cooperative research in future.

Wild caribou and muskoxen have always been a vital food resource for the people of Greenland as demonstrated by the abundant bone remains at archaeological site (Møhl 1972; Meldgaard 1986; Sandell & Sandell 1991; Gulløv 1997). Despite the enormous socio-economic changes that have occurred in Greenland during the past century, caribou and muskoxen remain species of cultural and economic importance (Rasmussen 1995; Sandell & Sandell 1998). Meat from these wild ungulates is an important source of income for professional hunters and the possibility of hunting caribou is important culturally and recreationally for non-professional hunters to maintain their contact with the land and access to "Greenlandic foods" (Marquardt & Caulfield 1996; Sejersen 1998). It is clear that, for wildlife managers on Greenland, a major objective is to provide for sustainable harvest of the wild ungulate populations.

However, the Greenland that is now entering the 21st century is very different from the Greenland, that entered the 20th century. The human population has increased by a factor of 5 and a market economy has developed (Lyck & Taagholt 1987; Grønlands Statistisk 1999). In addition, the human population has become increasingly mobile through the increase of modern boats with powerful engines (Mattox 1973; Nielsen 1999). Despite the low population density and lack of roads, few parts of Greenland where caribou or muskoxen occur are more than a few hours boat travel from human settlements. Hunting practices have also changed with the development of segregation between professional hunters and recreational hunters. As of 1998 there were 2,556 professional hunters and 7,601 recreational hunters registered (Grønlands Statistik 1999). Professional hunters are dependent on a diverse variety of prey species including crabs, fish, marine mammals, sea birds, ducks and caribou/muskoxen, depending on seasonal availability (Siegstad et al. 1999). These "local foods" are used by the hunter, sold or traded privately, sold to processing companies or sold at town markets. The professional hunters are currently trying to turn what has formerly been a form of subsistence into a profession that is able to maintain a modern standard of life in what is becoming a cash economy with a relatively high standard of living (Caulfield 1993; Marquardt & Caulfield 1996). Therefore the potential pressure on all natural resources, including caribou and muskoxen, is very high (Rasmussen 1995; Heide-Jørgensen & Reeves 1996; Born et al. 1998), and careful regulation of the harvest will be required to ensure its sustainability in the future.

Caribou in Greenland

The indigenous caribou found throughout western Greenland are of the subspecies *Rangifer tarandus groenlandicus*, the same as that of the Canadian mainland tundra and Baffin Island (Banfield 1961; Meldgaard 1986; Klein et al. 1987; Gravlund et al. 1998). Domestic reindeers from Norway were introduced into the region east of Nuuk in 1952. Genetic studies using microsatellites have confirmed that genetic introgression has occurred in both of the adjacent wild caribou herds, but not into the more distant herds north of the Sukkertoppen glacier or far to the south around Paamiut. Other releases of domestic reindeer, with the intentions of establishing feral populations, occurred on Disko Island, the Nuussuaq peninsula north of Disko Bay, Olrik Fjord in northwest Greenland and at Ammassalik on the southeast coast (Thing 1980; Meldgaard 1986). The present statuses of these feral reindeer herds are uncertain.

Because of the complex topography of western Greenland, the indigenous caribou are divided into an unknown number of local populations (Meldgaard 1986). The most important populations are located in 3 topographically separate areas along the southwest coast. There have been no systematic censuses, but sporadic estimates of population size are available for 1970, 1977, 1982, 1993 to 1996 and 2000-2001. These estimates indicate dramatic fluctuation in population size (from ca. 10,000 to 140,000). Although no information about the causes of these fluctuations is currently available, density dependence, climate and human impact (harvest) could be the main factors (Vibe 1967; Melgaard 1986).

During the 1990's and until 2001, hunting was permitted for a limited period of August-September, for both professional and recreational hunters. Official hunting statistics during the 20th century report harvests varied from a low of ca. 100 in the 1920's up to maximums of 10,000-17,000 in the 1970's. Harvests decreased to around 5,000-9,000 animals per year by 1983, when hunting records ceased. Hunting records began again in 1995, after hunting was once again permitted following the two-year prohibition 1993-1994. Harvest quotas were first introduced in 1995. Although initially low, e.g., 2,000 animals, in 2002 the harvest recommendation was for more than 27,000 animals. The previous year, 2001, of a quota on 24,000 animals, just over 10,000 animals were harvested. The impact of this harvesting regime, in interaction with natural processes, on population fluctuations, has not yet been fully evaluated.

Muskoxen in Greenland

Muskoxen were formerly only in northeast Greenland, with distribution expanding after the 1870's (Forchhammer and Boertmann 1993). Although systematic censuses are lacking, the population size was estimated at 9,000-13,000 individuals in 1990. In the early 1960's, 27 muskoxen were translocated from northeast Greenland to Kangerlussuaq in west Greenland. This population has grown to about 7,000-10,000 individuals by 2001. Six further translocations to other locations in west Greenland used animals taken from the Kangerlussuaq stock (Forchhammer & Boertman 1993).

Traditional harvest of muskoxen has been limited. From 1900 to 1950, Danish and Norwegian trappers harvested muskoxen in Northeast Greenland, and some animals were also captured live and sent to Alaska, Svalbard, Norway and zoos throughout Europe. Following the creation of the national park in 1974, muskoxen have been virtually protected in Northeast Greenland, although hunters may shoot those needed to feed their dogteams while hunting polar bears in the park. A small quota (250) has been allowed outside the national park on Jameson Land. The muskox population in this area has declined over the past decade. Between 400 and 1,000 animals are also harvested from western Greenland populations annually during the 1990's. These har-

vests did not prevent population increase. A better monitoring of population sizes, causes of fluctuations, and consequences of harvesting is required to ensure a sustainable development of muskox populations.

Issues in sustainable harvest of Arctic ungulates

Fundamental to effective management of ungulates is an understanding of their population dynamics (Gunn 1998). In alpine and Arctic environments, both the quantity and quality of forage available limit ungulates (Forchhammer & Boertmann 1993; Caughley & Gunn 1993). The amount of forage available per individual is influenced by density dependent mechanisms and density independent climatic factors like snow depth or icing (Forchhammer & Boertmann 1993). Reindeer are able to overgraze their forage supply (especially lichen pastures, Helle & Aspi 1983), the recovery of which can take many decades (Tveitnes 1980). Climatic events may make such over-grazing events even worse (Klein 1968). Populations of caribou in Arctic environments subject to strong environmental stochasticity (Vibe 1967) may therefore have the ability to boom and crash. Without large population of carnivores in Greenland, only hunting can help control population growth and stabilise population fluctuations. To what extent this is possible depends on local population dynamics and the quality of monitoring protocols and management strategies adopted.

Caribou and muskoxen have different life history strategies, foraging ecology and population dynamics (Gunn 1998). Population dynamics of caribou/reindeer have been studied extensively in Norway (Skogland 1989), Svalbard (Solberg et al. 2000) Canada, and Alaska (Caughley and Gunn 1993, Fancy et al. 1994), showing considerable intra-specific variation (Skogland 1989). Few data are available from Greenland (Meldgaard 1986), but we expect large variation along the geographical gradient of Greenland's west coast and between native caribou and semi-domestic reindeer. On a global basis muskoxen are less studied than caribou/reindeer, although most existing data on muskoxen comes from Greenland (e.g. Forchhammer & Boertmann 1993). Based on existing databases and on routine collection of information on harvested individuals, one objective is to document geographic variation in life history traits and population ecology of caribou and muskox in order to implement management plans useful at the local level.

Greenland needs to construct harvest management plans that incorporate the complexity of population dynamics in the Arctic (Forchhammer & Boertmann 1993; Caughley & Gunn 1993; Solberg et al. 2000). There is a wealth of theoretical and practical knowledge that can be used (Caughley & Sinclair 1994; Sæther et al. 1996; Lande et al. 1997). Efforts have to be directed towards the analysis of existing data, the acquisition of new knowledge and the implementation of management strategy at the same time. Such a project will take advantage of experience from knowledge of managed populations in other countries

Along with the "national" research on reindeer and muskoxen in Greenland several other research institutions and universities from abroad are conducting or planning related projects in Greenland. Furthermore, research on reindeer and vegetation is carried out in several Nordic countries. Therefore the idea also has been to gather key players and explore possibilities for future cooperation and networking. Here we report the workshop and its conclusions.

Workshop session I

Background – Sustainable grazing? - Abstracts

1. Sustainable reindeer husbandry in Sweden

Jon Moen, Dept. of Ecology and Environmental Science, Umeå University, Sweden

Reindeer grazing and the management of grazing resources in Sweden within the Mountain Mistra Programme: The programme, which deals with sustainable development and multiple land use, is a large multidisciplinary research programme involving economics, forestry, fish and wildlife resources, reindeer husbandry, tourism, and conservation issues. An evaluation of large-scale grazing by the semi-domesticated reindeer in Sweden does not indicate any extensive damage to the vegetation except at fences and enclosures on summer grazing grounds. There then followed a presentation of data on grazing effects, and a discussion of grazingeffects on plant biodiversity, which vary depending on productivity and foraging behaviour. Further data on the potential effects of climate change on tree-line position in the mountains where only a few percent of tree-less alpine heath may be left in a hundred-year perspective, were also presented as well as a discussion of methods used for estimating the status of food resources (lichens) on winter grazing grounds.

2. Snowmelt and characteristics of growth season in West Greenland

Mikkel Tamstorf, National Environmental Research Institute, Dep. for Arctic Environment, Roskilde, Denmark

Snowmelt and characteristics of growing seasons in West Greenland 1982-1998 AVHRR Polar Pathfinder data are used to map the distribution of snow cover and Normalised Difference Vegetation Index (NDVI) of West Greenland. The climate and plant zones of West Greenland are briefly described.

10 day averages of 1 km AVHRR image data from 1983-1996 was used for the estimation of the average season. The albedo was used for estimating the snow cover assuming full snow cover at albedo values above 0.9 and no or little snow cover at albedo values lower than 0.2. The NDVI was used to describe the greenness of the terrestrial surface during the snow free period.

A web-based tool for displaying and using the average years at each pixel of West Greenland was produced. The tool enables one to point at each terrestrial square kilometre of West Greenland and view the average snow cover and NDVI for the 1983-1996 period. The tool is easily extended with newer data that just have to be fitted to the 10-day composite periods and copied to the database.

Daily 5-km AVHRR Polar Pathfinder data from two locations near Kangerlussuaq and Nuuk are used when fitting models to the annual data of albedo and NDVI from 1982-1998. A symmetric sigmoid curve function is fitted to the near daily values of albedo for each year at both locations. The fit of the model is good with high significance ($P < 0.0001$, $r^2 > 0.9$). 5 parameters is extracted from the function: the albedo at full and no snow cover, time of start and end of the snowmelt and the time of maximum snowmelt. The time of start and end is used to calculate the length of the snowmelt. The growing season is 'modelled' by fitting a double-logistic curve function to the near daily NDVI values. This fit is also good ($P < 0.0001$, $r^2 > 0.9$) for all years at the two locations and enables the extraction of 4 parameters describing the growing season:

start and end of the growing season, level of maximum NDVI and time of optimum. The start and end of the growing season is used to calculate the length.

The functions can be used for obtaining the parameters describing the snow melt and growing season characteristics for any place on Greenland that has data available for fitting the functions. The parameters can be used in vegetation and herbivore studies as well as for general natural resource management. Linked with climate and vegetation studies the parameters might be able to explain some of the significant changes that have been observed among the large herbivores of Greenland since 1982. The AVHRR Polar Pathfinder project is continuing and will provide data in the some format building a time series of data for climate changes impact studies in West Greenland herds.

3. Various impressions from the monitoring work in Qussuk and Sangujaassuit north of Nuuk in the summer of 1997

Eric Steen Hansen, Botanical Museum, University of Copenhagen, Denmark

A number of plant communities more or less rich in lichens and so extensive that hyperspectral analysis was possible, were investigated in the two areas about 70 km north of Nuuk, viz. Qussuk and Sangujaarssuit, in the summer of 1997 (see: Hansen 2000). Qussuk is situated on Nordlandet/Akia in an area with many lakes and luxuriant dwarf shrub heaths and lichen heaths. Sangujaarssuit is a branch of the fjord, Ilulialik. The investigations were carried out near its head in an area with large scrubs of Alnus crispa. Vegetation analyses were based upon the ITEX-concept. Representative collections of phanerogams and lichens were made in both investigation ares. *Betula nana*, *Empetrum hermaphroditum*, *Ledum palustre*, *L. groenlandicum* and *Vaccinium uliginosum* are the dominant dwarf shrubs in the Qussuk area. *Cladonia stellaris* is usually the dominant lichen, but lichens such as *Cladonia mitis*, *C. stygia*, *Flavocetraria nivalis*, *Nephroma arcticum*, *Peltigera aphthosa*, *Stereocaulon alpinum* and *S. paschale* also cover large areas. *Salix glauca* and *Alnus crispa* form heath mosaics with the above-mentioned dwarf shrubs at the head of Sangujaarssuit. The composition of the lichen vegetation differs to some extent from that of the heath patches at Qussuk. *Nephroma expallidum* and a number of "frost boil lichens" occur commonly at Sangujaarssuit. Slides showing the monitoring work and general social life during the investigations will be presented.

4. Status muskoxen *Ovibos moschatus* and caribou *Rangifer tarandus groenlandicus* and feral reindeer *Rangifer tarandus tarandus* in Greenland

L. Christine Cuyler, Greenland Institute of Natural Resources, Nuuk, Greenland

There are both indigenous and introduced populations of muskoxen and caribou/reindeer in Greenland. Both are of economic importance, while caribou are also of cultural and political importance. Since both may occur from c. 82° N in the high Arctic south to 61°N in the subarctic, there is diversity in regional climate and topography, and each population's distribution, abundance, growth and harvest. There are regions where these species coexist, and others where one or the other is the sole large herbivore. Predators do not exist in Greenland, with the exception of a handful of wolves, which recently recolonized northeast Greenland.

Knowledge regarding the muskoxen of northeast Greenland is limited. Abundance has decreased where legal harvesting is permited in Jameson Land, which is close to Ittoqqortoormiut. The original muskox introduction to West Greenland occurred at Kangerlussuaq. All animals were captured in east Greenland. Muskoxen share the Kangerlussuaq range with caribou. Since the release of 27 muskoxen in the 1960's the population size has grown to an estimated

7,000 to 10,000 animals. Annual population growth, recruitment and density on the range are high. Overgrazing is a concern. There were 6 further releases of muskoxen in west Greenland (all captured in Kangerlussuaq). Extinction was immediate for one population, but otherwise growth has been typical. Specifically, the Ivittuut muskoxen have been carefully monitored and managed locally, since their release. In 2001 they numbered 287 animals with 27% calves. Muskoxen are the sole large herbivore of Ivittuut.

Caribou/reindeer inhabit west Greenland, with greatest abundance in the southwest. None exist on the east side of Greenland. The indigenous northeast Greenland caribou became extinct around 1900 and the introduction of feral reindeer in southeast Greenland is reported to have failed. Semi-domestic reindeer were first introduced to west Greenland in 1952 for the purpose of reindeer husbandry. Since then reindeer have been relocated to several locations for the purpose of establishing feral harvestable populations. Historically, caribou were found along most of the coast of West Greenland. Today there are several distinct populations and greatest abundance occurs on the diverse southwest Greenland coast. All populations combined they totaled c. 140,000 animals in 2001. Knowledge has improved in the past 5 years. The southwest coast has been divided into 5 caribou regions, which include 7 known populations. Further investigations may subdivide populations further, which could facilitate management actions. Present population sizes, densities and calf recruitment are often high and recent growth has been likely and perhaps rapid. The early 1990's hunting prohibition followed by low quotas, which were male-biased, coupled with the excellent annual calf recruitment could have promoted rapid growth in population size. Subsequently, overgrazing of the vegetation may be a problem for some caribou populations.

5. Plant diversity and grazing in the Scandinavian mountains - How does grazing impact plant diversity patterns?

Gunnar Austrheim, Department of Botany, Norwegian University of Science and Technology, Trondheim, Norway

There is a long tradition of pasturing semi-domestic reindeer and sheep in alpine and sub-alpine Scandinavian habitats, but present management regimes are questioned from a conservation point of view. In this review we discuss plant diversity patterns in the Scandinavian mountains in a global, regional and local perspective. The main objective was to identify processes that influence diversity at different spatial scales with a particular focus on grazing. In a global perspective the species pool of the Scandinavian mountains is limited, partly reflecting the general latitudinal decline of species but also historical and ecological factors operating after the latest glaciation. At the local scale, both productivity and disturbance are primary factors structuring diversity, but abiotic factors such as soil pH, snow distribution and temperature are also important. Although evidence is scarce, grazing favours local species richness in productive habitats, whereas species richness decreases with grazing when productivity is low. Regional patterns of plant diversity is set by, (1) the species pool, (2) the heterogeneity and fragmentation of communities, and (3) local diversity of each plant community. We suggest that local shifts in community composition depend both on the local grazing frequency and the return-time of the plant community after a grazing session. In addition, an increasing number of grazing-modified local patches homogenises the vegetation and is likely to reduce the regional plant diversity. The time scale of local shifts in community composition depends on plant colonisation and persistence. From a mechanistic point of view, diversity patterns at a regional scale also depend on the regional dynamics of single species. Colonisation

is usually a slow and irregular process in alpine environments, whereas the capacity for extended local persistence is generally high. Although the poor knowledge of plant regional dynamics restricts our understanding of how grazing influences plant diversity, we conclude that grazing is a key process for maintaining biodiversity in the Scandinavian mountains.

6. The status of large herbivores in the Alps

Anne Loison, Laboratoire de Biométrie et de Biologie Evolutive, Université Lyon, France

During the last decades, most of the populations of large herbivores increased in numbers as a result of specific management actions or by natural processes. This restitution of an abundant and diverse fauna, especially in mountain areas, is mainly perceived as positive, by, e.g., conservationists, tourists and hunters. However, large herbivores in mountainous areas may have an increasingly impact on ecosystem function and dynamics, through their interactions with plant communities, their role in shaping habitat, and their importance for large carnivores. Changes occurs rapidly and there are large gaps in our knowledge of mountain ecosystems. The traditional research approach based on single-species studies is still necessary, however an integrated approach using long-term studies (and experiments where applicable) should bring into focus (1) interspecific competition, (2) interaction between domestic and wild ungulates, (3) the role of predation, (4) the role of wild ungulates on plant communities, (5) the effect of space, landscape patterns and their changes on the dynamics of ungulates, (6) the evaluation of climatic variation on population dynamics, and (7) defining management strategies (e.g. through culling) to satisfy multi-user management objectives.

7. The population dynamics of Svalbard reindeer. What is the role of parasites?

R.J. Irvine, S.D. Albon, & A. Stien, CEH Banchory, Hill of Brathens, Banchory, Aberdeenshire, UK. (O. Halvorsen, Zoological Museum, University of Oslo, R. Langvatn, University Courses in Svalbard, Longyearbyen, Svalbard, Norway, E. Ropstad, Norwegian College of Veterinary Medicine, Oslo, Norway)

Svalbard reindeer (*Rangifer tarandus platyrhynchus*) are non-migratory, and occur in small (<10) groups but at comparatively high densities that fluctuate two-fold between years. Although the reindeer have no large predators, gastro-intestinal parasite nematodes, (principally *Ostertagia gruehneri* and *Marshallagia marshalli*) reach an abundance that depresses reindeer body condition. Compared with controls, treatment with anti-helminth drugs in April/May significantly increased the probability of individuals being pregnant twelve months later but had little effect on over-winter survival. Pregnancy in untreated control animals was significantly related to body weight, and independent of the intensity of infection with *O. gruehneri*, but not *M. marshalli*. Interestingly, the development of infection differs between nematode species. The prevalence of *O. gruehneri* is very low until the second summer of a reindeers life, compared to the apparently non-pathogenic M. marshalli which reaches adult burdens by the first autumn. These differences in the ontogeny of infection reflect differences in the life history patterns and transmission dynamics of the two species. They are consistent with the two-year time lag between O. gruehneri abundance and reindeer host abundance and thus a potential mechanism for explaining the instability of reindeer numbers, which is explored through mathematical simulations parameterised from the data.

8. Modification of high Arctic ecosystems by herbivores; pattern and process of Svalbard reindeer grazing

Rene van der Wal, CEH Banchory, Hill of Brathens, Banchory, UK

Large herbivores have verifiable and significant impacts on both temperate and tropical ecosystem structure and function. Herbivore impacts on Arctic systems, and particularly the mechanisms by which they influence plant communities, are largely unknown. High Arctic vegetation, commonly overlying permafrost soils, is often dominated by moss with very sparse vascular plant cover. We tested the hypothesis that large herbivores influence Arctic plant communities by altering the depth of the moss layer, leading to warmer soils and benefiting vascular plants. We surveyed 14 high-arctic sites with contrasting reindeer densities across Spitsbergen (76-80^{o}N). Deeper moss layers significantly depressed soil temperatures and summer grass abundance. Moreover, the abundance of grasses, but not total vascular plant cover, was positively related to the abundance of reindeer, with very low grass cover at sites with low densities of reindeer. In a soil temperature manipulation experiment we found a greater, positive response of grasses to increased temperature compared with non-grasses. These findings indicate that grazer impacts on moss depth, and subsequently soil temperature, may regulate vascular plant abundance and community composition because of the positive but growth-form-specific response of vascular plants to soil warming, leading to the promotion of grasses. Additionally, we observed increased abundance of grasses in the vicinity of bird cliffs, where soil nitrogen availability is very high, indicating that the indirect temperature-driven effects of herbivores may be combined with a direct effect on soil nutrient availability. We propose that the positive association of grasses and large herbivores in high Arctic moss-dominated systems results from two simultaneously operating positive feedback loops. Firstly, herbivore grazing and trampling reduces moss layer depth, leading to increased soil temperatures. Secondly, grasses benefit from grazers as a result of nutrients released from faeces and urine.

9. Role of Large Herbivores in Vegetation Response to Global Change in the Arctic

Christian Pedersen, Dept. of Biology, Pennsylvania State University, University Park, USA

Concern regarding global climate change, has lead to the idea that vegetation might mitigate the effects of climate change through carbon sequestration. The ability of the vegetation in the Arctic to do this is limited, in part, by nutrient availability. Because vertebrate herbivores exert considerable influence on plant biomass, soil nitrogen dynamics and species composition of plant communities, they may influence the ability of vegetation to function as a carbon sinks in the Arctic. In this study, we will investigate the influence of herbivory on the productivity response of vegetation to climate change in grazed and un-grazed areas. Use of environmental chambers will allow for manipulations of ambient and elevated temperature and CO_2 concentrations, and allow us to investigate the role of herbivory by caribou in the sequestration of carbon by vegetation in the Arctic.

Session II

Mapping important variable and Key Tools - Abstracts

1. Distribution of vegetation within caribou home ranges using telemetry and remote sensing data

Mikkel Tamstorf, National Environmental Research Institute, Dep. For Arctic Environment,, Roskilde, Denmark

Vegetation maps for two areas around Kangerlussuaq/Sisimiut and Nuuk/Fiskefjord have been prepared using satellite images and fieldwork. These are used in combination with satellite positions to describe the forage selection of caribou in West Greenland. The vegetation maps of the two areas are based on Landsat TM satellite data and covers in total 51,483 km^2. The presentation describes the data processing and fieldwork necessary for obtaining reliable vegetation maps from the Arctic region. The mapping resulted in 7 vegetation related cover types. Due to the large climatic gradient between the coastal and inland regions the mapped types are not consistent throughout the mapped area. An analysis of the plant distribution within each vegetation type at different locations along the gradient was therefore done. All results are distributed on a data-CD, from which the maps and descriptions can be downloaded and used. The accuracy of the maps was assessed using both traditional methods and fuzzy techniques. Not all cover types are mapped with the same degree of accuracy and most of the uncertainty is related to the lack of terrain correction. High-resolution digital terrain models covering the entire area of the two regions do not exist.

Fourteen (14) female caribous in the two regions were collared with satellite position transmitters in 1996 and 1997. The transmitters have delivered positions during the period from 1997 to 1999 describing the migrations of the caribou during two full years. The migration patterns are analysed and seasonal home ranges for the individual as well as grouped females have been prepared. The movement analysis shows that the patterns are not uniform among the caribou within the Nuuk region, but consisted of both stationary animals, that stayed summer and winter in the same area, and migrating animals, which moved to other areas during calving and between summer and winter. The utilisation distribution of the animals was used in combination with the vegetation maps to analyse the forage selection of the collared animals. The results from this showed the preference of the animals in the Nuuk region for lichen compared with the animals in the Kangerlussuaq region but also that preferences changed through the year. Home ranges and utilisation patterns for the collared animals are also presented on the data-CD with the vegetation maps.

2. Reindeer lichens and UV-B mapping, future scenarios

Eric Steen Hansen, Botanical Museum, University of Copenhagen, Denmark

Different physical and chemical characteristics of the complex of problems associated with ultraviolet radiation and the stratosperic ozone depletion caused by CFC-gases are outlined. Plant responses to UV-B radiation will be discussed, and examples both among phanerogams and lichens (Cetraria islandica, Cladonia mitis) will be presented. Living organisms have developed the following strategies to minimise damage induced by UV radiation: (1) organisation and movement of organelles to reduce the absorptive area or move the organelles out of the radiation area, (2) synthesis of scree-

ning compounds, which absorb and dissipate the UV radiation as fluorescence or heat, (3) synthesis of accessory enzymes or accessory pigments to protect cells from active forms of oxygen and (5) mechanisms to repair the damage to nucleic acids. – The effects of UV-B radiation vary between species and within varieties of the same species. The developmental stage of the tissue also influences the response. UV-B often causes a reduced biomass, and the radiation also influence on the competetive ecology between plant species and with other organisms. Some future scenarios from the Godthåbsfjord area in West Greenland and the Zackenberg area in East Greenland will be discussed.

3. Aims and methods in grazing ecology: Case studies from West- Greenland and Norwegian alpine habitats

Gunnar Austrheim, Department of Botany, Norwegian University of Science and Technology, Trondheim, Norway

The first study focuses on effects of reindeer grazing on Arctic tundra vegetation on the west coast of Greenland. Two different vegetation-monitoring techniques have been examined. (1) Small-scale community patterns in permanent plots. This approach focuses on repeated measures of changes in plant community patterns in reindeer grazed areas. A modification of the point intercept method – (cf. ITEX manual) is used for sampling plant community data. (2) Measures of lichen cover and biomass within 100 x 4 quadrates in a wintergrazed area at Nordlandet north of Nuuk (205 km^2). The approach focused on lichen cover, height and disturbance. Finally the study will evaluate methods for monitoring vegetation in reindeer grazed areas on the west coast of Greenland.

The second study focuses on grazing ecology in Norwegian alpine habitats: "Sustainable use of outlying land for livestock grazing: ecological effects of sheep grazing in alpine habitats". Our main aim is to identify methods for evaluating the sustainability of sheep grazing in alpine habitats. The general method will be to explore the ecological effects of sheep grazing at a high and intermediate level. Our response variables are plants, rodents, insects and the sheep themselves, in both a productive (Hol, Buskerud county) and an unproductive region (Setesdal-Vesthei, Vest-Agder and Aust-Agder counties). This approach will give us the possibility to estimate stocking levels with a strong versus an intermediate grazing pressure in the two contrasting habitats.

4) Development of a national monitoring system for landscapes in Sweden

Jon Moen, Dept. of Ecology and Environmental Science, Umeå University, Umeå, Sweden

A new nationwide landscape monitoring system in Sweden is currently being developed. The system will cover all habitat types, i.e., including mountains, forests, wetlands, agricultural and urban land, and is based on a hierarchical sampling scheme with remote sensing and field visits. A total of about 500 sites are planned, and about 80 of these will be in mountains areas. A survey was conducted to determine the monitoring needs of the various authorities, i.e., which variables needed inclusion in the system. The sampling will be based on remote sensing of 5 x 5 and 1 x 1 km squares where, among other things, land cover classes will be measured. A series of plots and transects will be laid out in these squares and detailed vegetation data gathered. I will focus on variables discussed in the mountains areas. The monitoring system will be initiated in 2003 and the planned revisit rate of the sites is every 5 years.

5. Plant-herbivore relationships in the Alps. Presentation of research plans

Anne Loison, Laboratoire de Biométrie et de Biologie Evolutive, Université Lyon, France

Studying the dynamics of large herbivore communities and the impact of large herbivore communities on landscape and plant diversity requires long-term studies. So far in Europe, studies have focused mainly on single-species dynamics and on the relationship between domestic ungulates and pasture biomass. I presented a network-based project, which aims at investigating the mechanisms of plant-herbivore relationships from the soil component to the human component, in a single site. We divided our projects in 3 parts. The first focuses on the functioning of herbivore communities, both wild and domestic. We will explore the determinant of forage and habitat selection, feeding regimes, intra- and inter-specific competition, and the dynamics at the community level. The second part will focus on the plants and the landscape, with one section on pastures, one on the forest-pasture ecotone, and one on forest regeneration. For both these parts, we will have an historical approach comparing plant and herbivore patterns in mountainsides with different history of use and management, and an experimental approach. The last component is the stakeholder's point of view and management of this grazing system in a multiuser context. This project will be based in the regional park of Les Bauges in the northern Alps and benefit from long-term monitoring and research of the herbivore components. It gathers several institutes, both research and management, in France, and aims at being part of a larger network on the study of grazing systems in Europe. Greenland would be a natural partner if a study could be conducted on the caribou/muskox/hare herbivore community.

6. Previous and ongoing vegetation monitoring in West Greenland

Kristjana Motzfeldt, Greenland Institute of Natural Resources, Nuuk, Greenland

Greenland with its area of 2,106,073 km^2 has approximately 407,440 km^2 ice-free area. In contrast to other Nordic countries, there is no private ownership of land. Greenland lies in six Arctic climatic zones ranging from high to low Arctic. The flora of Greenland, botanical composition and plant diversity is fairly well explored. There are 513 known species of vascular plants. 49 of these are classified as vulnerable or endangered. At protected sites in southern Greenland with summer temperature above 10^{o}C, longer growing season and sufficient precipitation, grows the white birch *Betula pubescens ssp. tortuosa* and rowan *Sorbus groenlandica* forests. Since GN was established in 1995, vegetation work has been emphasized on range for the large herbivores, reindeer, muskoxen and sheep.

In the late 1970s', conventional vegetations mapping was carried out in south Greenland and the areas carrying capacity regarding domestic sheep pasturing was evaluated. These vegetations maps have later been digitized. In 1996 vegetation mapping was carried out with satellite photographs on domestic reindeer range at Isortoq, South Greenland. The reindeer farming was established in 1973 and both number of animals and the size of the area have later been increased to approx. 1,500 km^2. In 1996 the grazing effects was estimated and one of the sub-areas (approximately 275 km^2, calving area) was found to be serious overgrazed, however most of the other sub-areas were in moderate or in good grazing condition. In the years 1997 to 2000 vegetation were mapped with help of satellite photographs in two areas of reindeer and muskox range in West Greenland, Nuuk, Sisimiut-Kangerlussuaq, and one for domestic sheep pastures in South Greenland. These areas

cover approx. 76,000 km^2.Vegetation analyses were based on the ITEX-concept for estimation of plant communities and coverage. Furthermore, plant preference during winter was investigated by analysing faeces and rumen content from reindeer in two areas, Kangerlussuaq and Nuuk/Akia. The Nuuk/-Akia area has abundant reindeer lichens, in contrast to the Kangerlussuaq area. The main result was that the intake of food was significantly different between the two areas. Reindeer in Akia ate more lichen, while in Kangerlussuaq they ate more graminoids and dwarfshrubs. In Kangerlussuaq the females had worse body condition (fat reserves) and had greater tooth wear compared to females in Akia. In Akia the females had significant lower content of rumen than in Kangerlussuaq. These results indicate that the female reindeer in Akia inhabits better range during winter with a higher nutrient in their food compared to the females in Kangerlussuaq.

Serious soil erosion is taking place in the sheep farming area in Vatnahverfi in southern Greenland. Three hypotheses have been launched as explanation for erosion; 1) the Norse farming and extensive agricultural utilization of the land around 1000 A.D., 2) present day sheep farming, and 3) worsening climate and increased sandstorm activity recorded around 1300 A.D. The area has been mapped on aerial photographs by classifying erosion according to erosions forms and by applying standard scales to assess the severity of soil erosion. All mapping data were digitalized, and analysed via geographical information system (GIS). A 5 year re-vegetation project was initiated in 2000. The purpose of this project is to help the natural vegetation cover the eroded areas. Preliminary results are promising.

Session III

Future plans in Greenland, cooperation and networking – Abstracts

1. Interplay between muskoxen and reindeer grazing: Habitat and herbivore population sustainability

Rene van der Wal and Justin Irvine, CEH Banchory, Hill of Brathens, Banchory, UK

To understand plant-herbivore interactions in Greenland we need to understand the interactive effects of the major grazers muskox and reindeer. Critical to the performance of large herbivores is the quality of their habitat, as demonstrated in the close relationships between lichen stands and reindeer performance in Northern Scandinavia. Although reindeer densities, and thus their impact on the vegetation, have fluctuated substantially during the last century, the reintroduction of a second large herbivore (muskoxen) to the West coast of Greenland, has radically changed the relationship between large grazers and their food supply on Greenland. Where tundra vegetation in the past has been subject to seasonal grazing at variable intensity by the migratory caribou, muskoxen are more sedentary and apply a year-round grazing pressure in areas where they have established. This leaves limited opportunity for swards to recover from grazing and will result in a muskox-driven vegetation succession away from lichen-rich to graminoid dominated tundra. The implications of lichen loss, particularly in reindeer wintering grounds may have significant impacts for the population dynamics of this species. Currently, all muskoxen populations on the West coast of Greenland are expanding into caribou dominated areas. Therefore, it is both timely and increasingly crucial to investigate the competitive interactions between these two herbivore species and predict their combined future effect on the vegetation.

The Kangerlussuaq area of West Greenland presents an ideal opportunity to determine the consequences of muskox expansion to both caribou populations and their habitat. Through the erection of carefully designed temporary (seasonal) and permanent exclosures, the differential impact of these two herbivores (and Arctic hares) will be determined. This will allow herbivore-specific plant species selection to be investigated and, over the longer term, the impact of each herbivore on the plant community structure can be detected. Secondly, herbivore interactions on animal performance and fitness could be tested by focussing hunting/culling efforts in such a way as to reduce the abundance of muskox relative to reindeer in one main area and contrast this with other areas that have different ratios in the densities of these two main herbivores. Combined with diet selection studies and information from the animal density manipulations, this project will generate predictions on the effect of competition between these species on the abundance of each other and their impact on the vegetation. From this, simple, reliable indicators of herbivore performance and vegetation condition will be developed which will facilitate a more quantitative approach to the setting of hunting quotas.

Specific objectives:

1. test whether competitive interactions between muskox and caribou do occur,
2. investigate the mechanisms that are involved,
3. develop indicators of grazing pressure to assist in planning a sustainable harvest.

2. Population division and variability in density and population dynamics among Greenlandic reindeer

Anne Loison, Laboratoire de Biométrie et de Biologie Evolutive, Université Lyon, France

Studies on caribou behaviour, foraging and habitat selection have been performed mainly in the Kangerlussuaq area, which is easily accessible. It is only very recently that a few individuals have been marked with satellite collars in two different areas, allowing better insights on spatial behaviour to be obtained. The first results point to complex spatial behaviour, where individuals from the same area exhibit different seasonal movement patterns. When following up on such detailed individual studies it is important to understand the interaction between individuals, how population distribution may change with increasing density, and where resource competition may occur. However, these detailed studies can only occur on a small range of the coast. In the meantime, caribou are monitored and managed on the basis of a division into 4 regions: North, Central, South, Paamiut, where populations are assumed to fluctuate in the same extend from year to year. This may mask a reality that is more complex, where each region could host several populations with varying levels of density and different population dynamics. As an alternative to mark and monitor individuals, we suggest to use genetics and GIS to describe the population structure in relation to the habitat fragmentation along the West Coast. The recent advance in genetics and analysis of genetic data allow now to assess genetic barrier, gene flows and population structure without pre-conceived assumption about the spatial structure. We will use these new methods and examine how the genetic structure corresponds with landscape features.

3. Climate and herbivores - influence of temperature and Co_2 on biomass and productivity

Christian Pedersen, Dept. of Biology, Pennsylvania State University, University Park, USA

Critical to the prediction of climate change and development of climate models is the understanding of herbivores on the productivity response of vegetation to climate change. The interaction between herbivores, temperature and CO_2 is important for plant species composition, productivity and biomass production in the Arctic. Herbivores might have a large effect on C sequestration and C exchange between vegetation and the atmosphere. This study will investigate the cumulative response of Arctic vegetation to simulated climate change and herbivores in natural field settings. The study will start summer 2002 in Kangerlussuaq and have a minimum 5-year time span. We will construct large enclosures to exclude caribou from certain areas. By using environmental chambers in the grazed and ungrazed areas, manipulation of temperature and CO_2 concentration will be performed. We will focus on functional plant groups like graminoids, shrubs, forbs, bryophytes and lichens and their response to grazing by caribou. C sequestration potential is largely dependent on plant functional groups rather than plant species per se. By monitoring the change in biomass and cover of the plant functional groups over time, we will be able to predict the effect of large herbivores and climate change on the C sequestration potential in the Arctic.

1. investigate climate and herbivore/influence of temp and CO_2 on biomass and productivity
2. response of Arctic vegetation to simulated climate change in natural field setting
3. importance of interactions between herbivore temp and CO_2 to species composi-

tion productivity, biomass accumulation in the Arctic

4. influence of herbivore on C sequestration and C exchange between vegetation and atmosphere

4. Future needs & plans: Caribou and muskoxen populations effects on range

L. Christine Cuyler, Greenland Institute of Natural Resources, Nuuk, Greenland

Today GN has a wealth of new information, as a direct result of the studies over the past five years, plus historical sources. Regarding caribou, there exists historical information on range condition and abundance, indices of body condition and size, population estimates and herd structures, fertility, range fidelity, parasites, diet, and the annual harvest records. Regarding muskoxen, there exists indices of body condition and size, abundance changes over the past 40 years at Kangerlussuaq, minimum counts and herd structures, diet, and the annual harvest records. For both species, local persons have been involved in monitoring and trained in methods and techniques.

Immediate future plans for 2002 include an analysis of resource selection by caribou plus further minimum counts and herd structures, which involve the use and training of locals. -Regarding vegetation and winter range in Kangerlussuaq there are planned initial studies for muskoxen range and the possible range.

In the long-term, 2003-, a vision statement for the direction of herbivore/range studies at GNI is necessary. Both summer and winter range must be considered. Interactions with other herbivores, e.g., Arctic hares, geese, might also be addressed. Regardless, it is important to get the message of our vision out to the broader academic community in order to attract collaboration. We need to identify the key indices for measuring change and the mechanisms for why changes occur. Bearing in mind, managers will still insist on our providing them with "numbers", i.e., population size estimates. In order to buy time we can recommend herbivore densities, which could conserve range quality and availability until better knowledge is obtained. This workshop established a network of several leading scientists and institutions. If funding can be found then future collaboration would provide a better scientific foundation for caribou and muskoxen harvest advice.

5. Range Use of West Greenland Caribou in relation to habitat, climate and disturbance

Mikkel Tamstorf, National Environmental Research Institute, Dep. For Arctic Environment,, Roskilde, Denmark

We suggest a project that uses remote sensing and GPS collars to monitor range use, migrations and behaviour of caribou in areas subject to disturbance from mining activities, hunting, tourism etc. Home range and migration patterns will be used in combination with existing terrain and vegetation knowledge to document the effects on the caribou forage selection and range use in order to compare ranges.

In East Greenland we have suggested a project on: Musk-ox range range in the Zackenberg area using GPS collars and relate results to climate change. (From East Greenland data on muskoxen and climate exist from various projects that started in 1995 (BIO-BASIS-programme - GEO-BASIS, CLIMATE BASIS and the MARINE BASIS).

6. Vegetation variability, distribution, radiation effects and coast inland gradients

Eric Steen Hansen, Botanical Museum, University of Copenhagen, Denmark

1. Continued studies of coast-inland vegetation gradients (Godthåbsfjord, Zackenberg, Scoresby Sund etc., see: Lund et al. 2000)

2. Additional studies of the vertical distribution of plants
3. Continued investigation and mapping of plants in ″white spots″ in reindeer grazing areas
4. Further studies of lichen biomass and lichen contents of reindeer faeces in reindeer grazing areas
5. Improvement of the methods used in evaluation of grazing degrees with the purpose of obtaining a better adaptation to Greenland conditions
6. Continued lichen growth rate studies
7. Continued studies of plant responses to UV-B radiation and general ″health condition″ of lichens
8. Measurements of snow depths and other parameters important for plant communities in reindeer grazing areas.

Session IV
Questions

Question 1 & 2:
What is sustainable management of Arctic tundra ecosystems? And what are the main scientific challenges related to a sustainable management of plant-herbivore interactions in the Arctic tundra?

Sustainable management, besides sustainability in harvest of living resources should also include conservation of the environment and biological biodiversity. To do this we need to understand the interrelationship between ecosystem, climate and human impact. Within this regard this workshop focused on terrestrial mammals, intra and interrelationships, herbivore interaction with vegetation, climate and parasite variables as well as human harvest and other impacts (disturbance etc.) in the West Greenland region. Particular care is needed in establishing baseline knowledge and in understanding and monitoring the environmental conditions and changes in order to maintain a sustainable use of these living resources.

Ungulate populations' sensitivity depends on stochastic events, ratios winter to summer grounds and quality and quantity of food. Stochastic responses are dependent on both demographic and spatial parameters. The large spatial scale covered by Greenlandic ungulates (north-south gradient) implies that big differences could be expected.

Greenland Institute of Natural Resources' role in large herbivores & overgrazing

Regarding large herbivores and range, Greenland Institute of Natural Resources has to develop a long-term monitoring which is comparable with future assessments. However, on a shorter term, there is need for a quick and cost-effective methodology to have an idea of rapid habitat assessment, animal's numbers, shrub height, soil erosion etc. A multidisciplinary research programme would substantially support integrated and adaptive resource management and monitoring. A long-term strategy funded by 5yr studies in collaboration with alliances from abroad - based on collaborative fund raising effort seems to offer the most realistic possibility to gain the needed knowledge. Also exploration of the existing information and integration into the planning needs to be carried out. The overall studies should be planned cooperatively and integrated to each other among all parties (research institutions) planning studies in Greenland.

Question 3 & 4:
Methods and tools in grazing. How could the main problems related to plant –herbivore interactions in Arctic systems be challenged and what information do the management agencies need?

The harvest of ungulates is presently based on a quota system where the central and local management (municipalities) issues licenses based on applications from hunters. To enable society to make the most of the harvest it is clearly preferable to have as predictable harvest as possible. Especially when quotas are high, as for reindeer during recent years, it seems difficult to fill the quotas. The major part of the quota (75%) is issued among the professional hunters to offer for sale at the local markets (brett) at the same time as most of the population have reindeer meat from own sports harvest, thus the market is overfull. At the same time as the nature of hunt and veterinarian regulations don't allow this meat to be turned into the commercial market. Predictability in the quotas could allow for building an industry around the harvest, thus make it possible to dispose a larger part of the

quota. A monitoring system that enables one to forecast trends in the population development and for example set annual quotas for 3 year periods would be preferable.

To be able to forecast shift in population development trends over large and remote areas one needs quick and efficient techniques. It is also essential to build the monitoring so that gathered material are processed and available for translation into management advice in a fast and efficient way. Several questions need to be addressed. How is this herbivore plant balance and how can we be able to predict when populations growing too large. How many animals can be within an area?

A number of rapid habitat assessments to address sustainability questions in the short term, as well as building up a database in the long term are necessary.

On a short term
Hunter reports on effort and different simple catch variables such as rump fat, estimated body weight etc. should be obtained annually. Furthermore, a local contact net should be established and instructed in simple vegetation monitoring. This kind of rapid habitat assessment could be targeted:

1. Faecal pellet density
2. Lichen height and cover
3. Shrub (Salix sp.) height and cover
4. Sign of soil erosion

Hunter reports must be simple, very clear, have a nice lay out as well as effort is put on explaining the hunters the inestimable value of returning them (including feedback). Data needs to be consecutively processed and evaluated and therefore calibrated to institute staff and resources.

On a longer term
A successful vegetation monitoring will need data on animal density and abundance. Long-term vegetation– monitoring could be based on a latitudinal as well as a coast inland gradient (lichen zone and steppe).

Emphasis should be put on the development of protocols for rapid habitat assessments which than can be carried out by local people across Greenland. Along with current data already collected on reindeer, a phenomenally strong database can be set up across three critical dimensions: latitude, level of oceanicity, and time (years). The long term database should be set up at GNI and would enable to set quotas safe in the knowledge that they are underpinned by sound scientific approach within a few years. At the same time, a scientifically exciting database will have emerged which can help in answering critical questions on plant-herbivore interactions in the light of global change.

In order to do this a pilot study on designing protocols has to be carried out. The protocols needs to be tested with the objective of demonstrating the implementation of the necessary monitoring of vegetation and herbivores to provide reliable, “rough and ready” indices from which the status of different herds/geographic areas can be interpreted. The results from a pilot study could act, as a fundament on which to base other more targeted grant applications, which if successful, would cover some of this work in future.

Lessons learnt/concluding remarks

The project plans and interest outlined by the participant at the workshop (above) has shown a wide range of research fields/plans with little overlap, but with a high number of common denominators from which each interest might draw large advantages by networking and direct collaboration.

The trend in both national and international research funding programmes today is large networks and the collaboration among several institutions. This workshop has been a first step in gathering researchers with common interests and where most have project interest in Greenland. The workshop has clearly shown that there is much to gain in further developing networking, put up joint project plans and applications as well as integrating ongoing research and monitoring. The reward will be better projects and less money spent by using common logistics, equipment and labour.

Co-operation among highly trained scientists from different institutions also will bring together a variety of specific scientific strengths held by the different participants/ institutes. This obviously has the potential of resulting in a faster learning curve, better monitoring procedures, better and more high ranked publications than by acting alone.

Finally, co-ordinated planning and direct project-cooperation will enable GNI to develop and establish appropriate monitoring procedures on ungulates and vegetation.

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Appendix 1
Workshop programme

Monitoring effects of large herbivores on vegetation in Greenland
21st-24th February – Nuuk.

Date	Time	Speaker/Chair	Title
22/2	10.30	Erik W. Born (acting dir.)	Welcome
	10.45	Arild Landa	Practical information
	11.00	ALL	Presentation round
	11.15	Arild Landa/All	What do we want to achieve - Needs/Reporting?
	12.00		LUNCH
		Chair: Gunnar Austrheim	**Session I: Background – Sustainable grazing?**
	13.00	Jon Moen	Sustainable reindeer husbandry in Sweden
	13.30	Mikkel Tamstorf	Snowmelt and characteristics of growth season in West Greenland
	14.00	Eric Steen Hansen	Various impressions from the monitoring work in Qussuk and Sangujaassuit north of Nuuk in the summer of 1997
	14.30	Christine Cuyler	Status of caribou and muskoxen in West Greenland
	15.10		Coffee Break
		Chair: Christine Cuyler	**Continued session I: Background**
	15.30	Gunnar Austrheim	Plant species diversity and grazing in the Scandinavian mountains
	16.00	Anne Loison	Status large herbivores in the Alps
	16.30	Justin Irvine	The population dynamics of Svalbard reindeer. What is the role of parasites?
	17.00		Coffee Break
	17.2 0	Rene van der Wal	Modification of high Arctic ecosystems by herbivores; pattern and process of Svalbard Reindeer grazing
	17.50	Christian Pedersen	Response of the tundra ecosystem to climate change driven by migratory grazers?
	18.20	Group/plenary	Question 1: What is sustainable the management of Arctic tundra ecosystems?
23/2		**Chair: Christine Cuyler**	**Continued session I: Background**
	09.00	Group/plenary/-Summary	Question 2: What are the main scientific challenges related to a sustainable management of plant herbivore interactions in the Arctic tundra?
	10.15		Coffee break

Date	Time	Speaker/Chair	Title
		Chair: Anne Loison	**Session II: Mapping important variables and key tools**
	10.30	Mikkel Tamstorf	Distribution of vegetation within caribou home ranges using telemetry and remote sensing data
	11.00	Eric Steen Hansen	Reindeer lichens and UV-B, future scenarios
	11.30	Gunnar Austrheim	Aims and methods in grazing ecology: case studies from West- Greenland and Norwegian alpine habitats
	12.00		LUNCH
		Chair: Mikkel Tamstorf	**Continued session II: Mapping important variables and key tools**
	13.00	Jon Moen	Development of a national monitoring system for landscapes in Sweden
	13.30	Anne Loison	Plant –large herbivore interactions in the Alps. Presentation of research plans
	14.00	Kristjana Motzfeldt	Previous and ongoing vegetation monitoring in West Greenland
	14.30		Coffee break
	14.50	Rene van der Wal and Justin Irvine	Interplay between muskox and reindeer grazing: Habitat and herbivore population sustainabillity
	15.40	Groups/plenary/-summary	Question 3: Methods and tools in grazing ecology. How could the main problems related to plant-herbivore interactions in Arctic systems be challenged?
24/2		**Chair: Eric Steen Hansen**	**Session III: Future plans in Greenland, cooperation and networking**
	09.00	Anne Loison	Future Project plans in Greenland
	09.15	Christian Pedersen	Future Project plans in Greenland
	09.30	Christine Cuyler	Future Project plans and needs in Greenland
	09.45	Mikkel Tamstorf	Future Project plans involving large herbivores and vegetation in Greenland
	10.00	Eric Steen Hansen	Future Project plans/main interests in Greenland
	10.10		Coffee break

Date	Time	Speaker/Chair	Title
	10.30	Groups + plenum	Question 4: Sustainability in a harvested Arctic system. What information do the management agencies need?
	12.00		LUNCH
	13.00	**Chair: Arild Landa**	**Continued session III: Future plans in Greenland, cooperation and networking**
		Plenum	Summary
	13.00	2-3 groups + plenum	What is missing in the proposed projects when looking back at decision on management needs?
		Plenum	Defining the common denominators for project plans
		2-3 groups + plenum	Future project co-operation within Greenland
		Plenum	Future networking?
		Arild Landa	Lessons learnt/concluding remarks?
	19.00		Farewell dinner at the Nature Institute

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