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NARP HIGHLIGHTS



CONTRIBUTIONS OF THE NORDIC ARCTIC RESEARCH PROGRAMME

Rapid Changes in the Arctic

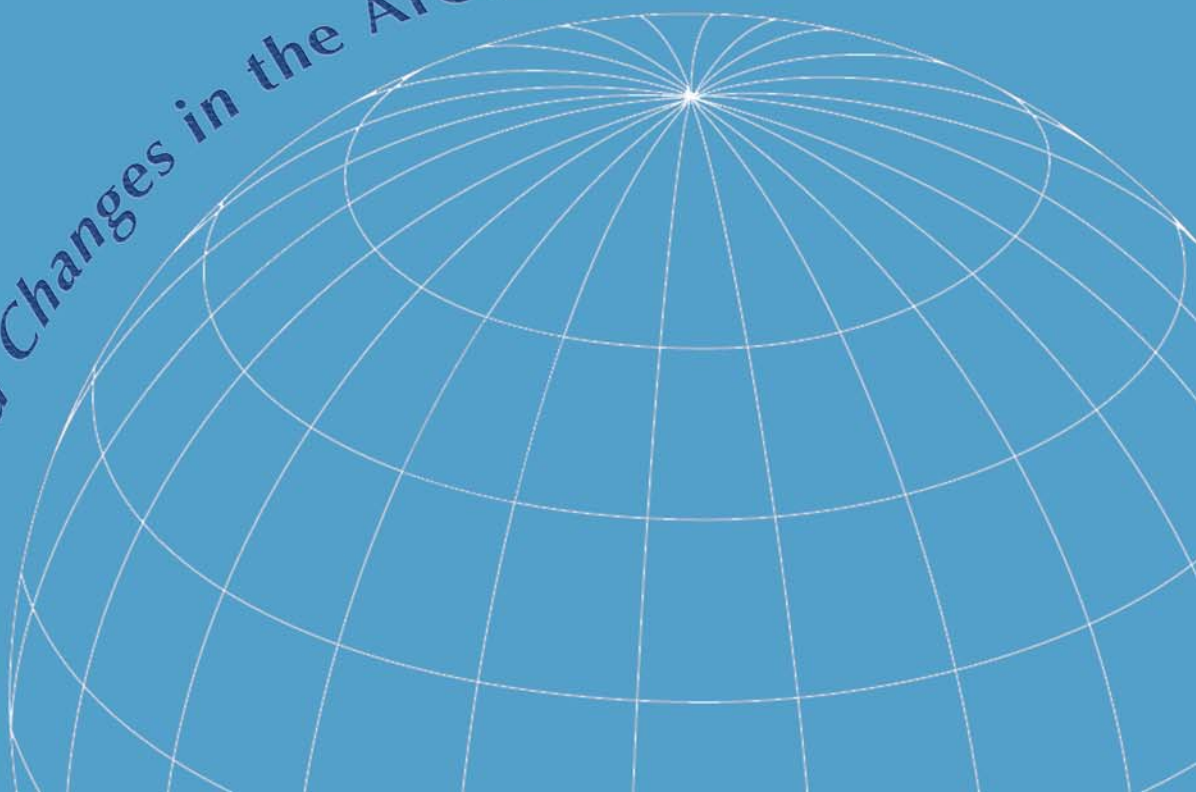


Table of contents

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Foreword 3

Research on land, sea and atmosphere

– Natural processes – land, sea and atmosphere –

Pollution and rapid climatic changes in the Arctic as recorded by lake sedimentary archives – JOHN BIRKS 6

Monitoring the flow of Atlantic water through the Norwegian and Barents seas using coastal water level data – THOMAS A. MCCLIMANS 7

Sources of airborne aerosol particles over the remote Arctic Ocean and their climatic impact – ERIK SWIETLICKI 9

Climatic change, carbon flux and living resources in the Nordic seas – PAUL WASSMANN 12

Investigating rapid climate change using Svalbard ice cores – ELISABETH ISAKSSON 14

The adaptation of organisms has economic consequences

– Biological diversity and environmental threats in the Arctic –

Cross-system analysis of the variation in the biological structure and dynamics of North Atlantic lakes related to variations and changes in climate and land use – ERIK JEPPESEN 18

Capability of arctic plant species to respond to rapid environmental changes – INGER NORDAL 20

Human impact and sustainable utilisation of subarctic birch forests in a changing environment – KARI LAINE 22

Short- and long-term fluctuations in animal populations in Lake Myvatn – a model for climatic and human impact on the ecosystem – ÁRNI EINARSSON 27

Opportunities for human life in the North

– Living conditions of the inhabitants of the Arctic –

Survey of living conditions in the Arctic: Inuit, Sami and the indigenous peoples in Chukotka and on the Kola Peninsula – THOMAS ANDERSEN 30

Life of the Norse in SW Greenland in 985-1500: Influence of environmental change on sustainability and farming conditions – NAJA MIKKELSEN 31

Development of methodologies for the evaluation of the socioeconomic and environmental consequences of mineral and energy industries in the Arctic and Subarctic – RASMUS O. RASMUSSEN 32

Forestry beyond the timberline: ecological and socio-economic factors affecting forestry in the context of rural development in the North Atlantic region – THRÖSTUR EYSTEINSSON 34



Foreword

The natural processes that shape the Nordic Arctic and Sub-arctic regions and especially the northern Atlantic Ocean are globally important. In the northern Atlantic, the southern warm ocean currents are replaced by currents from the cold Polar region. This process has a notable impact on both regional and global climate. The prevailing climate conditions, in turn, significantly contribute to the biological resources and, even more widely, to the possibilities of people to maintain favourable living conditions in the northern regions. Arctic plants and animals live in extreme conditions, and even minor changes in these conditions may affect their ability to survive. Short-term climatic changes that take place within a generation are mostly governed by changes in ocean currents. However, our knowledge of these processes continues to be inadequate. There is a call for international research on the living conditions of people in the North in relation to the goals of sustainable development. The level of public interest in Arctic matters is high, and the Nordic countries should therefore assume increasing responsibility for Arctic research especially in Europe.

The Nordic Council of Ministers established a Nordic Arctic Research Programme (NARP) for the years 1999–2003. The programme board consisted of representatives of all Nordic countries, the Faroe Islands and Greenland. The coordinating secretariat of the programme led by Dr. Kari Strand was in the Thule Institute at the University of Oulu. The programme with the total budget of DKK 31 million was a significant resource for Nordic research in the Arctic and it provided a particularly good opportunity for Nordic cooperation and research networking. Outstanding work on a variety of Arctic issues has been made through

the programme's 63 projects. A great number of young students have greatly benefited from their study visits in Nordic laboratories and active networks were established within the programme. In addition, cooperation with researchers from the Faroe Islands, Greenland and Iceland improved during the programme.

It has become clear during the course of the Nordic Arctic Research Programme that there is an urgent need for multidisciplinary scientific Arctic studies also in the future. Especially, the trends and amplitudes of environmental changes in the Arctic are still poorly recorded and not fully understood. The rapidly changing socio-economic conditions in the Arctic, especially the Russian Arctic, require special scientific attention.

This publication describes the main goals and highlights of selected NARP projects and also recognised the common need for further coordinated Nordic Arctic research. Highly diverse projects were included in NARP. Some projects were active throughout the whole NARP lifespan, while some projects, e.g. those for organising a conference, were supported only for one year. The following pages introduce the project's highlights grouped under three themes: Natural processes - land, sea and atmosphere; Biological diversity and environmental threats in the Arctic; and Living conditions of the in-habitants of the Arctic. •

*Matti Saarnisto, professor
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Nordic Arctic Research Programme*

*LINKAGE OF OCEANIC
CURRENTS BETWEEN THE
NORTH ATLANTIC AND
THE POLAR SEA*

*RESPONSE OF ARCTIC
PLANTS AND ANIMALS
TO RAPID CHANGES*

*MANAGEMENT OF
NATURAL RESOURCES
AND SUSTAINABLE
DEVELOPMENT*

*HUMAN WELFARE AND
COMMUNITY VIABILITY
IN THE ARCTIC*



The Nordic Council of Ministers

The Nordic Council of Ministers, set up in 1971, is a cooperative body that serves the governments of the five Nordic countries. The Nordic Council of Ministers implements the practical aspects of Nordic cooperation in all policy areas. The Secretariat of the Nordic Council of Ministers in Copenhagen is responsible for the operational aspects of Nordic cooperation and programmes. The plan and priorities for the Nordic Arctic Research Programme have been specified by the Nordic Science Policy Council, which is an advisory committee and expert group for the Nordic Council of Ministers in the field of education and research.

The Nordic Council

The Nordic Council is the interparliamentary body involving the members from the parliaments of Denmark, Finland, Iceland, Norway and Sweden as well as the three autonomous areas: the Faroe Islands, Greenland and Åland. The Nordic Council was established in 1952. The individual Nordic parliaments appoint the 87 members of the Nordic Council. The Nordic Council takes initiatives and acts in an advisory and supervisory capacity on issues and matters of interest to official Nordic co-operation.

Nordic Research Co-operation

Nordic research co-operation, which takes place between the countries of Denmark, Finland, Iceland, Norway and Sweden, as well as the autonomous territories of the Faroe Islands, Greenland and Åland, is an integral agent of the co-operation conducted at a broader European and international level. Nordic co-operation increasingly reaches out to include also the adjacent areas – Estonia, Latvia, Lithuania, North-West Russia and Arctic regions. The Nordic Ministers for Education and Research have agreed to give the Nordic countries a leading position in competence development and research, with the emphasis on development of human resources and to stimulate the exchange of experience and development of research and innovative Nordic initiatives in this field.

Research on land, sea and atmosphere

– Natural processes – land, sea and atmosphere –



Pollution and rapid climatic changes in the Arctic as recorded by lake sedimentary archives

ACTIVE NETWORKING
THROUGH THE
SUCCESSFUL POLARCLIM
WORKSHOPS

CLOSE RESEARCH
COLLABORATION
BETWEEN BERGEN,
HELSINKI AND UPPSALA

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*13 project partners
Years 1999 – 2003*

The project "Pollution and rapid climatic changes in the Arctic as recorded by lake sedimentary archives" (POLARCLIM) expanded Nordic expertise in the detection and assessment of rapid climatic changes and temporal trends of the spread of pollution in the Arctic. Project aims included establishing a network of 10 scientists and 15 doctoral and graduate students and postdoc researchers in four Nordic countries and Svalbard; improving the training and mobility of young researchers by issuing travel grants and training grants to allow them to learn specialised skills in laboratories in another Nordic country; organising graduate-level training courses and four workshops on topics in Arctic palaeoecology; and launching a small pilot-scale field research project for teaching purposes in the Lyngen Alps in northern Norway, involving geological, palaeoecological and chemical approaches.

Training of young researchers

There has been considerable training of young Nordic researchers in various aspects of Arctic palaeoecology and palaeoclimatology, particularly in quantification and numerical data analysis, field techniques and data interpretation. This training has been backed up by taxonomic workshops and exchange of material, research visits to POLARCLIM laboratories and laboratories in the UK and active networking through the various successful POLARCLIM workshops. These have been held on Svalbard (2001) and in Bergen (2000, 2003), Copenhagen (2003) and Helsinki (2003). The workshops have covered topics such as environmental changes in the Arctic, land-ocean relationships in the Arctic, pollution and palaeoecological studies on Greenland, use of Bayesian statistical ap-

proaches in environmental reconstruction and the limnology and palaeolimnology of Arctic lakes.

Modern organism-environment calibration data sets and associated transfer functions have been developed in Finland, northern Sweden, Norway, western Greenland and Svalbard through training in modern quantitative techniques. The transfer functions have been elegantly validated against historical climate data by the Abisko group and applied to Holocene sequences to derive quantitative reconstructions of the past climate and lake water pHs for several Arctic areas. Through POLARCLIM networking, several multi-proxy studies have been made possible, involving groups in Umeå, Helsinki and Bergen. The Umeå group has detected and quantified the extent of pre-industrial atmospheric pollution of lead and mercury in arctic Sweden and western Greenland.

Completion of a large, multi-proxy investigation on recent environmental change and atmospheric contamination were recorded in lake sediments on Svalbard. The results indicate major biotic changes in the last 50-100 years that parallel similar changes in arctic Finland and the high Canadian Arctic. The Svalbard study has revealed the low-atmospheric contamination over much of Svalbard and the remarkably dynamic nature of lake biota in this high Arctic archipelago. The results were published as a special issue of the *Journal of Paleoclimatology*.

Through POLARCLIM, there has been very close research collaboration between Bergen, Helsinki, and Uppsala, resulting in the compilation of a modern pollen climate calibration data pool of 304 samples, which has been used to reconstruct the Holocene climate for arctic Norway, Sweden, Finland and the Kola

Peninsula. This subproject has been described in several papers in scientific journals such as *Boreas*, *The Holocene* and *Quaternary Research*. As a result of POLARCLIM, there is now a very effective network of palaeo-ecologists and palaeolimnologists in Arctic Fennoscandia with a new generation of young researchers, who have benefited greatly from POLARCLIM networking, training courses and collaboration. •



Monitoring the flow of Atlantic water through the Norwegian and Barents seas using coastal water level data

The flux of Atlantic water into the Nordic and Barents seas is vital for the existence of life in this corner of the world. Coupled circulation model experiments have indicated a possible weakening of the global thermohaline overturning, causing concern about the stability of the inflow and its sensitivity to global and regional changes. There have been several attempts to estimate and monitor these fluxes, but most of the monitoring efforts have been performed using expensive arrays of current meters. The main objective of the project was to assess the possibility of using coastal water level measurements for monitoring the flux of Atlantic water through the Nordic and Barents seas into the Arctic Ocean, and to estimate the effects on sea ice variations. The project has improved our understanding of climate variability in the area. The results, combined with transport time scales, will be helpful for predicting climate variability. Due to the close relation between climate variability and fish

population parameters, the project may also result in more reliable advice for the development of fish stocks.

This project was extended to a European scale by including the region from the Rockall Trough to the Kara Sea. The EU 5th Framework Programme project was named "Monitoring the Atlantic Inflow toward the Arctic" (MAIA). Algorithms computed on the basis of the analyses of historical data were subjected to a validation period of in situ measurements of currents, hydrography, bottom pressures and neutrally buoyant drifters during the period of May 2000 to November 2001.

The results show that barotropic slope currents can be monitored with good accuracy on a 5-day average by using coastal water levels and off-slope satellite altimetry. These currents are the "fast-track" for heat supply to the Barents Sea and the Svalbard region. Off-slope baroclinic transports can be monitored with monthly resolution using satellite altimetry and

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*6 project partners
Years 1999 – 2001*

seasonal variability of density.

The density of Atlantic water in the Nordic seas depends on the balance between the major inflows. There was observed to be a larger-than-normal inflow past Scotland and a lesser-than-normal inflow in the Faroe Current during the validation period. Estimates of the total inflow of Atlantic water were made for the period 1978–2002. Hindcast periods of greater inflow agree with periods of reduced ice cover in the Barents Sea and the warming of the Atlantic core in the Arctic Ocean. There is as yet unknown transfer between the baroclinic and

barotropic transports, depending on season and latitude. These appear to be strongest in the Faroe-Shetland Channel and in the Barents Sea opening. A better network of tide gauges in the North and improved capabilities of satellite altimetry in ice-infested waters are needed. The accuracy of the method can be improved by monitoring bottom pressures on the shelf and off-shelf. Data from the validation study in 2000–2001 and all public reports from the MAIA project are available on a CD-ROM at the British Oceanographic Data Centre [www.bodc.ac.uk]. •

The main objective of the associated project “Rapid transport of pollutants in drift ice to melt-down regions near Atlantic inflows” was to pursue the MAIA project’s efforts and to focus more on the questions of biodiversity and living conditions in the northern regions. More specifically, the transport routes and transport speed of pollutant-laden ice to the region and the rate of melt-down at the fronts were analysed in search for more efficient monitoring strategies.

Sea ice can accumulate pollutants from atmospheric deposition: in shallow water directly from the bottom sediments and in the deeper ocean from the mineral and biological particles present in the near-surface water. Once ice-borne, these pollutants can travel thousands of kilometers without significant dispersion. The accumulation of atmospheric deposition is like reverse entropy: gathering rather than spreading the pollutants. This process is further enhanced as the ice can be large, mimicking physical accumulation akin to bioaccumulation in the food web. The melting regions have high biological productivity due to strong stratification. Areas of high production and high pollutant concentrations may affect the seafood used for human consumption. Examples of this can be the Hopen Deep in the Barents Sea and the Yermak Plateau north of Svalbard. The results of MAIA and other efforts by the participating institutes show important fast-track routes of the surface currents along ocean fronts and bottom slopes. To accomplish further application of these results, the network was expanded to include circulation in the northern regions and ice chemistry. The efforts of this collaboration were expected to support the AMAP (Arctic Monitoring and Assessment Programme) and the Norwegian Transport and Effects Programme. The evidence indicates that drift ice is potentially an important transport route for pollutants to marine food supplies in the North. The results were presented at the AMAP meeting in Rovaniemi and at the annual meeting of the Association of Norwegian Oceanographers in Bergen. A further presentation was given at the Arctic-Alpine meeting in Tromsø in February 2003. The project defined future tasks to measure and model the accumulation of pollutants in first-year ice on its way towards the melting fronts near Svalbard and Iceland. Of heavy metals, the focus is on Hg because it is enhanced at polar sunrise, and because there is significant input from coal-fired power plants around the world. There are several organic substances that affect the Arctic food chain. These can be extracted from the same ice and snow samples. The transports to and within the drift ice have to be estimated from numerical models validated against field data. The Norwegian Polar Institute, with its experience in field work and contaminant studies in this region, will promote this project in the future.

Sources of airborne aerosol particles over the remote Arctic Ocean and their climatic impact

In the summer of 2001, the Swedish Polar Research Secretariat organised an expedition to the Arctic Ocean on the Swedish icebreaker Oden. The Atmospheric Research Programme of the Arctic Ocean Expedition 2001 (AOE-2001) was a continuation and development of the successful research carried out on previous Swedish icebreaker expeditions to the high Arctic in 1991 and 1996. The central Arctic Ocean is a region particularly sensitive to climate change due to positive feedback mechanisms, such as the increase in surface reflectivity (albedo) associated with a decrease in ice cover induced by enhanced warming. Little is currently known about the negative feedback mechanisms that might counteract the ongoing melting of pack ice in the Arctic and thus also help to mitigate the climatic consequences of the shrinking polar ice cap. The main objective of the AOE-2001 (see <http://www.fysik.lu.se/eriksw/aoe2001/aoe2001.htm>) was to quantify the impact of aerosols on climate and to increase our knowledge of how natural aerosol particles are produced and transported in the arctic atmosphere. The research programme is international and interdisciplinary and covers five fields: marine biology, gas and aerosol chemistry, aerosol physics, meteorology and modelling.

AOE-2001 field experiment

Most of the AOE-2001 activities were carried out during a 3-week ice drift when the ship was moored to drifting sea ice at about latitude 89°N. Research was carried out both aboard the ship and on the ice. Data were also collected with the help of kites, balloons and a helicopter. The field experiment was designed to (1) provide a description of the microbiology of the water and

ice, the nutrients present, productivity and sedimenting material; (2) determine the properties of the surface microlayer and its possible role in influencing the nature of particles produced by bubble bursting; (3) make shipboard measurements of the chemistry and physical properties of aerosol, trace gases, cloud-active particles, radioactive tracers and electrical conductivity; (4) conduct a lengthy and continuous series of measurements of mixing processes in the atmosphere from the surface to above cloud top; (5) assess horizontal homogeneity of the near-surface atmosphere and (6) obtain as many vertical profiles as possible of trace gases and aerosols in various size ranges.

The expedition (AOE-2001) to the central Arctic mostly north of latitude 85°N addressed the need to study marine life forms and their products in water and ice, especially the ways in which the products of marine life forms get into the air, the evolution of the particles produced and their growth up to sizes large enough to allow condensation into clouds. The main objective behind the efforts was to determine whether these naturally generated particles and clouds would constitute a positive or negative climate feedback upon temperature forcing. The Arctic has been identified as the region on Earth that is the most sensitive to anthropogenic climate perturbations. Both the extent and the thickness of the Arctic Ocean pack ice have been observed to be diminishing in response to global climate warming.

A suite of remote sensing meteorological instruments were deployed on the icebreaker Oden, and later also on the ice, to provide a continuous record of vertical profiles of wind speed and direction, temperature and clouds in the lower troposphere. When combined with regularly released rawin soundings, atmos-

THE ARCTIC HAS BEEN IDENTIFIED AS THE REGION ON EARTH THAT IS THE MOST SENSITIVE TO ANTHROPOGENIC CLIMATE PERTURBATIONS

THE CENTRAL ARCTIC OCEAN IS A REGION PARTICULARLY SENSITIVE TO CLIMATE CHANGE DUE TO POSITIVE FEEDBACK MECHANISMS

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*4 project partners
Years 1999 – 2003*



pheric moisture was also monitored. More detailed studies of the arctic boundary layer turbulence and mixing require an undisturbed environment. Oden affected the measurements by causing disturbing air flow and noise from fans and hydraulics. The ice drift was devised to alleviate these problems. Neighbouring ice floes were also utilised for some measurements.

The summertime arctic boundary layer was shallow, ~200 m deep, but well mixed and very moist. Near-surface temperature mostly remained between $-1.5 - 0^{\circ}\text{C}$, controlled by the melting points of sea and fresh water. Near-surface relative humidity was typically $> 95\%$, rarely dropping below 90% . Low clouds prevailed, with cloud bases commonly at ~ 100 m, and fog appeared frequently. However, visibility outside fogs was surprisingly good (> 20 km) even when the cloud base was low. This is probably due to the lack of aerosols, which prevented the formation of haze. The boundary layer was capped by an inversion that occasionally became very strong ($\sim 20^{\circ}\text{C}$). Specific humidity often increased over the inversion. The top of the inversion was typically at ~ 600 m. Low-level jets occurred infrequently and were located within the inversion. Thus, while the boundary layer is controlled by local surface properties and turbulence, the free troposphere retains its characteristics from areas beyond the

Arctic Basin, often for days. The inversion marks the interface between the two. During a few week-long periods, series of synoptic-scale weather systems appeared. However, no or only light precipitation was the most common observation. Weaker and shallower mesoscale fronts appeared frequently.

The biological activity of the open lead surface microlayer was found to strongly influence particle production over the pack ice region, which in turn will influence cloud properties in the area. Similar processes transferring particulates from the surface microlayer to the air (bubble bursting) should be operative in the world's oceans.

Results and conclusions

The ice drift phase of the expedition started in early August 2001, but it may already have been early summer in the upper water column for the planktonic community. Most of the phytoplankton present consisted of small, flagellated forms, while most of the meso-zooplankton biomass was composed of copepods. Primary and bacterial production rates were measurable but not high. The highest densities were always found in the surface microlayer. The production of climate-relevant dimethylsulfide (DMS) and its precursor, dimethyl sulfonium propionate (DMSP), were determined for the first time in these high Arctic waters and were also constrained to the ocean surface mixed layer (0-20 m in depth). The DMS and DMSP concentrations were comparable to those of temperate oligotrophic regions but much lower than those observed at the biologically rich ice edge a few weeks earlier. Nonetheless, carbon export was measured past 50 m, and it remained fairly constant throughout the water column for the duration of the drift.

Most of the atmospheric non-sulfate particles > 10 nm had close counterparts in the surface microlayer of the open leads. Concentrations of such particles in the microlayer sometimes exceeded 10^{14} ml $^{-1}$. Bubble bursting seemed to be capable of providing aerosol particles that can eventually form cloud droplets.



The microlayer particles appear to be identical with marine microcolloids. The helicopter and balloon/kite measurements further indicated that the formation of very small particles was indeed taking place below the clouds or in regions recently occupied by cloud or fog, and they were often found in sharply delineated regions. The earlier hypothesis that such formation only takes place above the clouds could therefore be rejected.

Accumulation of proteins and amino acids in the lead microlayer together with the much larger population of airborne bacteria than documented in previous expeditions suggest that, as hypothesised, the bacterial decomposition products of Arctic biota may be involved in aerosol particle formation processes. Primary liquid organic particles, fragments of diatoms and bacteria were again observed in the accumulation mode atmospheric particles (diameter > 100 nm), enhanced during days with particle nucleation. More generally, accumulation mode particles seemed to have more than one component. Oxidation products of DMS often surrounded insoluble Aitken mode

(20 nm < diameter < 100 nm) particles (perhaps mixed with soluble organics) and bacteria or other organisms. Some had sea salt components as well.

The earlier conclusion that particles grow by accumulation of oxidation products of DMS was again supported. The difference is that, instead of having to grow from nucleated particles, growth occurs on already sizeable primary Aitken and accumulation mode particles. The time taken to reach CCN (Cloud Condensation Nuclei) size must therefore be greatly reduced – it is a more efficient way of producing CCN. Our new scenario of arctic aerosols thus greatly increases the possibility of climate feedback effects since there is greater involvement of biological processes than with DMS alone. •

Climatic change, carbon flux and living resources in the Nordic seas

THE NETWORK
INVOLVED STUDENTS,
YOUNG SCIENTISTS
AND SENIOR
SCIENTISTS

SUSTAINABLE
DEVELOPMENT IN THE
NORDIC SEA REGION

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21 project partners
Years 1999 – 2003

The network on climate change, carbon flux and living resources in the Nordic sea started in 1999 and continued in 2002, refocusing on a pan-arctic perspective. The project aimed at exchanging knowledge and enhancing competence building among marine biologists and physical oceanographers. It involved students, young scientists and senior scientists.

The purpose of the project was to estab-

lish and maintain co-operation within a scientific network to illuminate the following interdisciplinary questions: (1) What is the impact of climate change on natural systems in terms of carbon sequestration, plankton production and vertical export of biogenic matter and renewable resources? (2) What are the consequences of global change for the dominating species and the general functioning of marine the ecosystem? (3) What is meant with "sus-

Subduction of Atlantic water and climate variability in the Barents Sea: its significance for atmospheric CO₂ removal and advection of plankton into the Arctic Ocean
Years 2002 - 2003

This was a student course headed by Paul Wassmann, organised as a part of the NARP symposium "C flux and climate change: The Nordic contribution to a pan-arctic perspective" that took place in Hotel Sigulda, Sigulda, Latvia, in November 1-7, 2002.

After introducing their specific research topics in the form of posters, the students worked actively in two working groups on the following topics: (1) Do polynias contribute significantly to C sequestration in the Arctic? Consider air-sea exchange, estimates of new production and measures of POC flux to the benthos (using the North Water polynia as a model polynia), and (2) How might certain functional components of the marine food web (e.g. mammals, zooplankton, etc.) respond to a polar ice cap that continuously decreases in extent (space) and duration (time). Consider the impact on points critical to export/retention or non-linear.

Both the students' and the teachers' feedback reflected the great success of the course. The Canadian colleagues actually wished to copy it for their students. The students were very enthusiastic. They were introduced to the entire field of arctic C flux studies, covering everything from physics to air-sea exchange, pelagic cycling, vertical export and benthos. Nordic and non-Nordic experts, some of them the best experts in their field and country, attended the course. The students were eager to use the opportunity to discuss with the guest speakers. As most were PhD students, this exchange was important for the progress of their studies. Such a successful student course would not have been possible without NARP. The students obtained sufficient information about pan-arctic phenomena to indicate that concerted action beyond the "sectorial" interest of the neighbouring states is necessary. The Nordic perspective often called for by North American scientists, was put forward probably for the first time. Co-operation enabled the Nordic countries to show up internationally.

tainable development” in the Nordic sea region, and what are the consequences of global change for sustainable development? (4) What is the role of the marginal ice zone and the increased fresh-water run-off for the overall functioning of the arctic environments with regard to global warming? (5) Is there significant feedback from the Nordic sea region to the global system? These questions were addressed in annual meetings of



36 scientists and students from 15 institutions from 7 countries. With participants from all of the Nordic countries, Greenland and the Faroe Islands, the meetings brought together detailed experience from the entire geographical area. The most important fields in physical, chemical and biological oceanography, natural resources and modelling were covered. This is the first overview on the physics, chemistry, carbon flux and plankton dynamics in the European sector of the Arctic produced by Nordic scientists. This enabled us to organise concerted Nordic research endeavours.

The co-operation between the partners increased considerably, and they met regularly in different contexts such as symposiums, EU and Nordic meetings at different levels, research projects and also through student exchange. A permanent network, ARCTOS, which involves all partners, has been established. Integrated research took place through two large research projects: “CABANERA” and “On Thin Ice”. Partners in the network were involved in the ECOGREEN application to EU, headed by the National Environmental Research Institute (NERI), and “Trophic interactions of the pelagic ecosystem over the northern Mid-Atlantic Ridge”, application to Iceland headed by the Iceland Institute of Marine Research.

We intended to use the ARCTOS network to act as policy makers in designing research strategies. The project enabled education of the first generation of Nordic PhD students in physics, chemistry, carbon flux and plankton dynamics. Finally, a successful workshop on the arctic data set from the project “Climatic variability and vertical carbon flux in the marginal ice zone in the central Barents Sea” was organised. The results were published as a volume in the *Journal of Marine Systems* under the title “Seasonal C-cycling variability in the open and ice-covered waters of the Barents Sea”. The second successful symposium on C flux and climate change was titled “The Nordic contribution to a pan-arctic perspective”. Nordic oceanographers met for the first time with top experts in arctic oceanography from Canada, USA, Germany and Japan. ANRP gave an answer to the question “What is the European contribution to Arctic oceanography and climate change”. •

Production, food web dynamics and biological origin of compounds involved
in aerosol formation
Year 2001

The central Arctic differs greatly from the lower-latitude oceans. The main rationale for establishing the aerosol-cloud-climate relationship in the Arctic, an area representative of perhaps only 10% of the world's oceans, is that the area has a disproportionately high meaning. While the meteorological and biological characteristics are certainly different from those at lower latitudes, the processes involved are expected to be similar. The project concentrates on these processes.

The ultimate aim of this project in relation to the Arctic Ocean Expedition 2001 (AOE-2001) was to improve the accuracy of the models used to simulate climatic change by reducing uncertainties associated with the indirect climate effect of aerosols. A major part of fulfilling this aim was to assess what feedback processes might be involved and to find out their implications for both regional and global radiative forcing. A multitude of both positive and negative climatic feedback mechanisms are conceivable. These are inextricably linked with one another, which further adds to the complexity of the problem. A distinctive feature of the international project is its interdisciplinary nature, as it involves contributions from biology, chemistry, physics, meteorology and modelling.

Investigating rapid climate change using Svalbard ice cores

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Years 1999 – 2003*

This project focused on the different climatic and environmental parameters using ice core records collected from Svalbard. Ice cores are well known for being one of the best archives for information of the past climatic and environmental changes. Svalbard is situated in a climatically interesting area and vulnerable to the temperature changes in the North Atlantic Current. Several ice cores have been drilled at Svalbard ice fields over the years. In general, the results from the earlier ice cores studies have suggested similar major climatic trends as recorded in other ice cores from the Arctic. However, many questions remain concerning the tim-

ing of events and the shorter time-scale changes as well as the need to determine how much the original records have been altered by melting.

Ice core records from Svalbard

A 121 m deep ice core was retrieved from Lomonosovfonna, the highest ice field on Svalbard in April 1997. Dating with a glaciological flow model suggests that the core contains about 800 years of climate and environmental information. Our analysis covered the most common substances, such as Na⁺, K⁺, Mg²⁺, Ca²⁺, Cl⁻, NO³⁻, SO₄²⁻, MSA, acidity (H⁺) and

δ¹⁸O. We also performed some analyses of trace metals (Hg), PAH (polyaromatic hydrocarbons) and organic carbon. The latter has never before been analysed in ice from Svalbard. Aspects of the impact of the local industrial development on Svalbard and long-range transport from industries in the south were revealed. During the spring of 1998, a Japanese drilling team with Norwegian participants drilled a 118 m deep core on the summit of Austfonna, and in April-May 1999 a core of 289 m was successfully retrieved. Based on the volcanic eruptions detected with this method, the core has been dated to about 1200. The Austfonna ice cores have been

analysed in 0.25 m parts (equivalent to 3-10 years) for the same components as the Lomonosovfonna core.

Results

The $\delta^{18}\text{O}$ data from the ice cores suggest that the 1900s was by far the warmest century during the past 800 years. One of the parameters to compare is the commonly used temperature proxy in ice cores, the $\delta^{18}\text{O}$ record, and the air temperature data from Longyearbyen. They show correspondence on a multi-year basis. This suggests that the core site reflects the local climate, which is why we consider the oxygen isotopes to be of high value as proxy temperature records. One study compared in detail the methane sulphonic acid (MSA) record, which is a proxy for marine biogenic produc-

tion, and the sea ice record over the 1920-1997 period. The results suggest that the two are closely related. MSA concentrations are higher for warm years with reduced ice cover. Years with little sea ice probably enable more dimethylsulfide (DMS) production and thus more MSA, and vice versa. The prevailing easterly winds suggest that the conditions in the Barents Sea should have a strong influence on the amount of MSA deposited on Lomonosovfonna. MSA may indirectly reflect larger-scale changes in the region, suggesting the possibility to use MSA as a proxy for past local climate on a decadal scale.

The $\delta^{18}\text{O}$ record from Austfonna corresponds to the August sea ice record from the Barents Sea over the period from 1600 to the present, suggesting that precipitation is directly influenced by

the distance to the moisture source. Because the August sea ice extent is also a proxy for the Northern Hemisphere mean annual temperature, we believe this correspondence to be a useful climatic signal. The sulfate records from the ice cores show a sharp increase in deposition in the 1950s, but the Lomonosovfonna records show an increase starting much earlier around 1850. This is earlier than has been reported in Greenland, which may suggest that the pollution situation in Europe can be monitored better with Svalbard ice than Greenland ice.

The following conclusions were derived from the project: (1) Svalbard ice cores provide information about major trends in the atmospheric variability of both climate parameters and pollution history, even though the results may have been somewhat affect-



ed by melting; (2) the recent Svalbard ice cores are estimated to cover at least the past 800 years. The 20th century is estimated to

have been the warmest century during this period. (3) The termination of the Little Ice Age around 1900 appears to have been very

rapid and connected with significant changes in atmospheric circulation. •



A red research ship with two masts is sailing through a field of ice floes in the Arctic. The ship is positioned in the center of the frame, moving towards the viewer. The water is a deep blue-grey, and the ice floes are white and irregularly shaped. The sky is overcast with soft, grey clouds. The overall scene conveys a sense of exploration and research in a cold, remote environment.

The adaptation of organisms has economic consequences

– Biological diversity and environmental threats in the Arctic –

Cross-system analysis of the variation in the biological structure and dynamics of North Atlantic lakes related to variations and changes in climate and land use

EXAMPLE OF A WELL-FUNCTIONING NETWORK OF RESEARCHERS FROM THE NORDIC COUNTRIES

THERE IS A PRESSING NEED FOR MULTIDISCIPLINARY RESEARCH FOCUSING ON THE BIOCOMPLEXITY OF ECOSYSTEMS

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The primary objective was to elucidate how variation and changes in climate and land use influence the biological communities, trophic interactions and biodiversity of North Atlantic lakes on both a short-term and a long-term scale. We established conceptual and empirical models to forecast the effects of climatic changes on arctic lake ecosystems. The approach included comparative cross-system analyses of data from approximately 300 North Atlantic lakes covering a wide temperature gradient ranging from oceanically influenced lakes on the Faroe Islands over subarctic lakes in Iceland, western Greenland and northern Norway to high Arctic lakes in Greenland and Svalbard. Within this gradient, the annual mean temperature ranges from -16.4 °C to +8.6 °C and seasonal variation from 25.4 to 6.7 °C. Additional data from lakes in Antarctica and Arctic Canada were included. The gradient covers examples from ice-free to permanently ice-covered lakes and comprises lakes located in catchment areas with different bedrock, soil types and anthropogenic impacts, e.g. domestic sewage, fertilisation, sheep farming and hydropower dam construction.

Some of the key findings

Fish play a key structuring role in arctic lake ecosystems. Studies of the trophic structure of these lakes as well as analyses of biological remains in the sediment have shown that the presence of fish leads to a major decrease in large-bodied zooplankton and invertebrates of near-

shore areas or sediment due to predation. The impact seems less intense in Faroese lakes compared to the colder and less species-rich lakes in Greenland. Predation on invertebrates is not, however, translocated to the next level in the food chain (e.g. phytoplankton), which is apparently strongly controlled by nutrients. The presence of fish also alters the pigmentation of various zooplankton. Pigmentation becomes less intense, presumably to reduce the risk of predation by visually hunting fish. It does, however, increase the risk of UV damage. Laboratory experiments have shown decreasing pigmentation of copepods in connection with an increase in the risk of fish predation. Analyses of sediment cores covering the entire Holocene have shown major changes in trophic structure during the past 8,000 to 10,000 years. These include changes in the relative importance of the benthic and pelagic systems that can most likely be attributed to landscape development and changes in climate. Studies of Icelandic lakes have shown a significant difference in biodiversity and nutrient status in lakes situated in areas with differences in bedrock composition. Studies in Greenland have shown that the chemical environment and biological structure of shallow lakes are very sensitive to year-to-year climate changes. Factors such as precipitation, the duration of snow cover and summer temperatures are important for the development of benthic and planktonic communities. The present studies of five Faroese lakes indicate that their overall species richness is low compared to lakes at similar latitudes in continental Eu-

rope, most likely owing to spreading barriers. This makes the lakes sensitive to both intentional and accidental introduction of new species. The studies show very large variations in top-down control by fish, depending on the fish community composition, and also indicate that the cascading effect on phytoplankton biomass and composition is low. Preliminary analyses suggest that the environmental effects of climate changes on arctic and subarctic lakes are more significant in lakes with fish than in fishless lakes.

The results will be of great importance for the evaluation of how climatic changes will influence lakes in the Arctic and sub-Arctic. The results are thus included in the Arctic Climate Impact Assessment (ACIA) Scientific Report. The project members have contributed to the harmonisation of monitoring programmes that will serve as the basis of decision-making in the future. We also believe that this first comprehensive analysis of Faroese lakes will be of great interest not only to scientists but also to the islanders.

Among other things, the NARP project has resulted in the formation of a well-functioning network of researchers from the Nordic countries, which, following the NORLAKE symposium, has also encompassed a number of other Swedish, Norwegian, Finnish, Icelandic and Danish groups. We have written the first book ever on Faroese lakes and published several joint scientific papers. We have also created a large network of the world's leading researchers in the fields of neolimnology and palaeolimnology. The co-operation is expected to result in the harmonisation of monitoring activities, a new joint research project, a comprehensive international database and several papers and reviews to be published in international journals.

The Nordic countries are still in need of multidisciplinary research focusing on the biocomplexity of ecosystems especially in relation to climate and human impacts. As we see it, there is now also competence within the established group to design far-sighted and productive research projects. •



Capability of arctic plant species to respond to rapid environmental changes

PLANT SPECIES AFFECTED BY RAPID CHANGES WILL OFTEN BE AT THE MARGINS OF THEIR DISTRIBUTION

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The response to rapid changes in arctic plant species is dependent on the degree of genetic variation and the capacity for dispersal. Without genetic variation within populations and without capacity for dispersal, arctic plant species may suffer or even die out due to rapid changes in climate, for example. Natural selection can only work on genetic variation, which is essential for the species to be able to adapt to new conditions. Capability of dispersal allows the species to spread to other localities and/or communicate genetically with other populations and thereby create new genotypes potentially able to cope with the changing conditions. The breeding systems of the plant species are of paramount importance for the level of genetic variation and gene flow. A certain amount of outcrossing is often indispensable for genetic diversity and adequate gene flow among populations. The species most drastically affected by rapid changes will often be at the margin of their distribution. When compared with their main area of occurrence, marginal populations are often less genetically varied and have less biotic interaction with, e.g., pollinators and herbivores. It is within marginal populations that the colonisation of new areas will take place, and in such populations the adaptation to new conditions will be the most demanding.

The following plant species were studied in the project: *Saxifraga hirculus*, *Campanula uniflora*, *Honkenya peploides*, *Armeria maritime*, *Dryas octopetala/integrifolia* complex and *Silene acaulis*. Seed banks were also studied. It turned out that a considerable number of species are found in seed banks in the Arctic. The study also resulted in five master's theses and the publication of two scientific articles.

Main results

The following questions were asked and answered in this NARP project:

Do arctic plant species reacting positively to environmental manipulations (e.g. temperature increase) possess larger genetic variation than species that react less to such manipulations?

The following table was compiled from published results and our own findings (marked with *) (page 21).

There appears to be no correlation between the vegetative response to the temperature increase and the degree of genetic variation. Nor is there a correlation between the temperature response and the breeding system. The only correlation was observed between the breeding system and genetic variation: outcrossing species have the highest gene diversity.

Do arctic plant species in marginal populations possess a different functional breeding system and less genetic variation than larger and more centrally positioned populations?

Two of our species occur in marginal positions: *Honkenya peploides* occurs marginally in the Arctic, whereas *Saxifraga hirculus* occurs marginally in Denmark. The study yielded contradictory results: *Honkenya* displays low genetic variation within its central distribution and high gene diversity within its marginal position. The genetic variation of *Saxifraga hirculus* is high in the Arctic and low in the more marginal boreal area.

Do arctic plant species with an established persistent seed bank possess higher genetic variation than species without a seed bank?

There was information available on 27

Species	Vegetative response on temperature increase	Ploidy level	Genetic variation within population Arctic Boreal		Autodeposition	Pollination M = mixed mating AL = outcrossers AU = selfers
<i>Ranunculus nivalis</i>	++	6x	?		0.1-0.3	M
<i>Silene acaulis</i>	+++	2x	+++ (*)		0.01	AL
<i>Papaver radiculatum</i>	++	6x-8x	(+) (*)		0.9-1.0 (*)	AU (*)
<i>Oxyria digyna</i>	+	2x	?		0.7	M
<i>Saxifraga oppositifolia</i>	0	8x	+++		0.0-0.2	AL
<i>Honkenya peploides</i>	+++ (*)	4x	+++ (*)	+	0 (*)	AL (*)
<i>Saxifraga hirculus</i>	++ (*)	4x	++ (*)	+	0 (*)	AL/M (*)
<i>Campanula uniflora</i>	0 (*)	4x	+		1.0 (*)	AU (*)
<i>Dryas octopetala</i>	+	2x	+++ (*)		0.4	M

species with regard to their occurrence in seed banks and their genetic variation. Ten species occurred in the seed bank, 4 of which showed some level of genetic variation and 6 no genetic variation. Of the 17 species not represented in the seed bank, 7 displayed high genetic variation and 10 little to no genetic variation. There hence seems to be no correlation between the occurrence in seed banks and the level of genetic variation.

Do arctic plant species distributed in different areas possess different levels of genetic variation, and can migration and population history explain the pattern?

We found generally abundant genetic variation in the species with an outbreeding mating system. Very little genetic variation was found in the species with a selfing mating system. The study of *Dryas integrifolia/octopetala* and

Silene acaulis gave a clear phylogeographic signal: The North Atlantic does not represent a

strong barrier to gene flow in contrast to the land bridge connecting the eastern and western Greenlandic populations. This is also supported by the fact that the populations of *Silene acaulis* from Tromsø and Abisko are genetically less related than, for instance, the populations from Tromsø and Jökuldalur in Iceland.



Do arctic plants with different demographic turnover rates display different genetic

population structure?

The short duration of the project did not allow for the monitoring of individual plants, to directly determine average plant age and

turnover rates. The following table is compiled from our results (marked with *) and other sources. •

Species	Generation time	Level of genetic variation	Breeding system
<i>Saxifraga hirculus</i>	M *	+++ *	AL *
<i>S. oppositifolia</i>	L	+++	AL
<i>Silene acaulis</i>	L *	++ *	AL *
<i>Lychnis alpina</i>	S *	++ *	M *
<i>Dryas octopetala</i>	L *	++ *	M *
<i>Honckenya peploides</i>	L *	+++ *	AL *
<i>Papaver radiculatum</i>	S *	+ *	AU *
<i>Campanula uniflora</i>	S *	+ *	AU *

Human impact and sustainable utilisation of subarctic birch forests in a changing environment

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The project established a Nordic research network focusing on the responses of the subarctic birch ecotone to the rapid changes in climate and land use practices. It was useful to prepare and maintain a joint EU project about the sustainable utilisation of subarctic birch forests in a changing environment called "Human interaction on the mountain birch ecosystem; implications for sustainable utilisation" (HIBECO).

Climate and insects

Birch forests that form the alpine or arctic tree lines are unique to northwestern Europe. Comparative remote sensing studies have revealed a change in vegetation over the last 40 years in Finnmarksvidda, northern Norway. Blueberry

(*Vaccinium myrtillus*) and dwarf cornell (*Cornus suecica*) are currently more common than 40 years ago. In contrast, the lichens preferred by reindeer have decreased in abundance. The reason for this change is believed to be a combination of changed climate and changes in human activity in the area, such as overgrazing by reindeer. Similarly, there has been an increase in the extent of birch forests in some areas as a result of climate change and better conditions for birch regeneration. As a result, the coverage of mountain birch forests at Maze in Finnmarksvidda, Norway, has increased by about 90% during the last 45 years.

Birch forests are usually dominated by relatively young trees. Only a small proportion are more than 100 years old, and different age classes dominate in different areas. The reason

for this is the recurrent outbreaks of various insects than can kill individual stems, local stands or, in some cases, even areas of several hundred hectares of birch woodland. Different insects are important in different areas: in coastal areas the winter moth (*Operophtera brumata*) and microlepidopterans (*Argyresthia retinella*) are the most important, while the autumnal moth (*Epirrita autumnata*) is the most important in more continental areas. Cold winter temperatures (below -35°C) kill the eggs of autumnal moths and restrict insect outbreaks both geographically and locally. The outbreaks do not occur at regular intervals in the more continental areas in eastern Fennoscandia, and forests on valley floors are often saved due to temperature inversion.

The work done during the HIBECO project enhances our possibilities to predict the risks of insect outbreaks under changing climate in different parts of northern Europe. Higher winter temperatures will increase the frequency of insect outbreaks in continental areas, but may not affect the defoliation risk in oceanic areas. On the other hand, the rising summer tempera-

tures may restrict the area and intensity of outbreaks due to increased pressure from the natural enemies of defoliating insects. The outbreaks in different areas are often, but not always, synchronous over large areas. A high degree of inbreeding of *Betula pubescens* population with the dwarf birch (*Betula nana*) has been shown. One of the important findings from the study was that birch individuals with a polycormic (multi-stemmed) growth form were much more resistant to insect attacks than monocormic (single-stemmed) trees. This is thought to be due to the more effective inbreeding of dwarf birch in polycormic trees than in monocormic trees and the better defence against insect attacks in the *Betula nana* population.

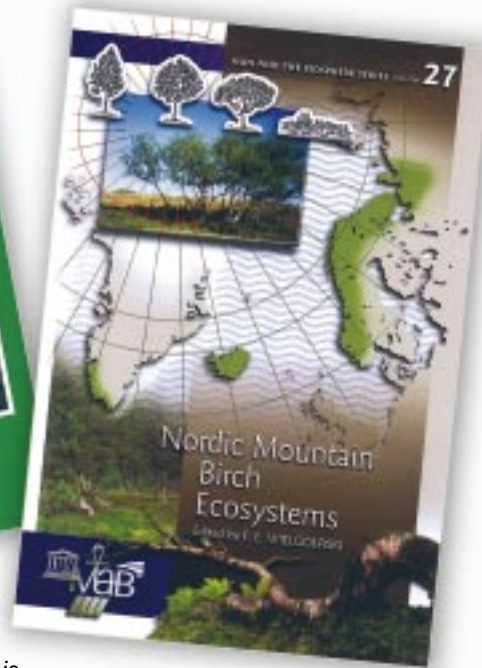
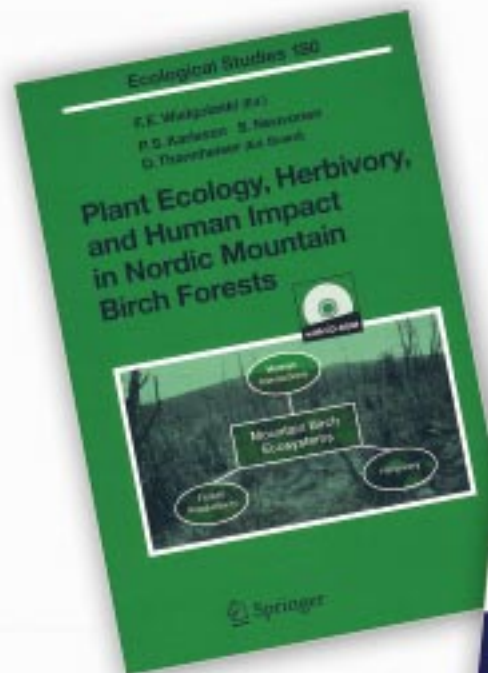
Climate may also be a direct threat to birch. At present, the injuries by extreme winter and spring temperatures are of relatively small and local importance, but this type of threat may become more important in the future with the changing climate. The present study has shown that especially the southern alpine birch ecotypes may be more subject to spring frost damage at present than before be-

CLIMATE CAN BE A
THREAT TO BIRCH

HUMAN-BIRCH
RELATIONSHIP IS SEEN
AS A CRUCIAL PART OF
THE LOCAL LIVELIHOOD

SOAGIS SÄLLENII –
BIRCH THE PROVIDER





cause they lose their hardiness too early. This damage may lead to reduced growth during the following season. On the other hand, mountain birches show marked phenotypic plasticity in their phenology and other characteristics. This may improve the ability of mountain birch to cope with changing climate. A transplant study indicated that the northern coastal birch provenances are better able to adapt to different photoperiods and temperature changes than birch of more continental origin.

Reindeer and sheep

The number of reindeer in northern Fennoscandia has undergone large spatial and temporal variation. Many recent studies indicate that the pastures are overgrazed. A review of the existing literature on experimental studies of reindeer grazing on different pasture components shows consistent reduction of lichen coverage in grazed areas. Birch tends to have lower coverage or biomass, lower height and lower seedling density in grazed areas, while grasses tend to have a higher coverage and biomass in grazed areas. In the more oceanic parts of northern Europe, sheep often browse in mountain birch forests. Heavy grazing by sheep in Iceland has resulted in not only vegetation damage, but also widespread erosion,

which may be very difficult to redress.

Parallel experiments were carried out in the HIBECO project in Finland, Scotland, Iceland and Greenland to study the effects of the severity and timing of simulated sheep/reindeer browsing on birch saplings. The overall indications from these experiments were that simulated browsing in winter was the least detrimental to the regrowth of birch. The spring and early summer effects were mostly intermediate, while late summer browsing had the most detrimental effects on sapling growth. Increasing severity of simulated browsing had increasingly detrimental effects on growth particularly in late summer. In general, birch is very resilient to browsing and capable of partial compensatory growth. However, if the browsing continues for more than a few years, it is likely that the effects become increasingly apparent as the resources of the saplings are repeatedly depleted.

Past and contemporary use of mountain birch resources

The land use changes related to cultivation and reindeer herding have been monitored regularly in the Maze and Ohcejohka regions since the 1960s, even before the initiation of the present

study. An emphasis was placed on monitoring the vegetation cover, which shows the impacts of land use changes ranging from meadows to reforested meadow forests and from heat forests to meadow forests. However, the lichen forests at higher altitudes remained despite apparent overgrazing by reindeer. The history of human settlements and traditional use of birch forest resources was investigated through interviews. A questionnaire was used to collect information from the local population: the aboriginal Sami and immigrant Norwegians and Finns. The HIBECO research team completed more than 140 interviews with individual and institutional users of mountain birch in northernmost Finland, Norway and Sweden in communities with Finnish, Norwegian, Sami and Swedish populations. For example, the emergence of Maze in Norway was identified as an important location for both reindeer herding during the winter and the agricultural settlement of the 300 to 400 inhabitants. A further analysis of age and gender structure revealed societal and cultural shifts in the Sami community, which had become more diversified. During the same period, Maze experienced a shift from reindeer herding with reliance on local renewable source, including birch forests, into a highly concentrated but limited agricultural sector and a small but strong sector based on tourism. These activities had an impact on the socio-cultural life of the community. Land use practices, such as birch utilisation, have con-

siderably decreased with respect to the use of birch for fuel, construction and crafts.

The interviews indicate that the human-birch relationship is considered a crucial part of the local livelihood. Local residents claim unconstrained access to this resource as a right and object to interference by government authorities. In this connection, extensive use and removal of birch wood for sale by seasonal cabin owners is perceived as a threat to the continued availability of mountain birch for local use. As for the environmental conditions, the birch on the Finnmarksvidda plain is part of the northern timberline forests, and its reproduction and growth are thus susceptible to changes in its productivity for use by humans and domestic animals. Sami people have stressed that birch trees should be harvested between the age of 20 and 40 years, possibly up to 60 years, since the prime life expectancy of birch is up to 80 years. The use of intricate local environmental knowledge in carefully selecting suitable trees for use will maintain the high level of productivity in the mountain birch ecosystem. In a separate study, long-term mechanical trampling combined with reindeer grazing was found to influence the structure and function of vegetation and soils.

In Ohcejohka in Finland, a panel discussion between local stakeholders and external scientists was organised on the use of mountain birch. This event was an attempt to bridge the still existing information and knowledge gap

between users and researchers. Furthermore, a 30-minute video, entitled "Soagis Sállenii – Birch the Provider" and depicting the intricate relationship the Sami have with the mountain birch was produced by Maria Sofia Aikio and Niillas A. Somby.

Based on an assessment of the interview material, some proposals were made con-





cerning for present practices and future possibilities of managing the use of mountain birch in northernmost Europe. There are obvious differences and conflicts of interest over appropriate management systems at the local, regional and national levels.

Management of mountain birch forests

Logging and lowering of the water table for cultivation and farming have, through time, interfered with the natural growth of meadow forests and their species composition (biodiversity), especially in the river valleys. The rapid expansion of agricultural land, infrastructure and roads have had an impact on the plant species composition in the "swamp forests" dominated by birch and willows in river valleys. On the other hand, as a consequence of the abandonment of cultivated fields, significant re-growth of birch forests has occurred, which has led to fewer species adapting to the semi-natural Sami landscape and the agricultural landscape. Military training has caused damage to the mountain birch forest environment in the inland parts of

the Tromsø and Finnmark counties in Norway. Damage by off-road traffic is often of a linear type. These tracks have caused soil erosion and damage to wet mires, which may affect the habitats of waders, birds, insects and other animals. In heath-type forests, especially on the borderline between forests and treeless areas, overgrazing by reindeer and sheep has also been a problem during the past decades. In order to know more about how to manage the northern mountain birch forest systems, we have interviewed managers, farmers, reindeer herders, military officers and craft workers. Their suggestions may lead to more sustainable development of these forests, that is, use of the forests without destroying them in the long run.

Combined effects

The defoliation of mountain birch forests by insects is obviously an important disturbance factor in northern ecosystems, and a combination of insect defoliation and heavy grazing by (semi)domestic animals may become a problem. The risk of insect outbreaks and spring frost damage may increase in certain areas if the minimum winter temperatures become higher. Sustainable sheep and reindeer herding in mountain birch forests requires lower animal densities than currently found in many areas. Lower animal densities are essential for the recovery of lichen pastures and birch seedling establishment, whereas moderate grazing may improve growth in established mountain birch forests. The results from the study indicate that, in the most heavily grazed areas, such as Maze and Ohcejohka, sustainable land use would imply a temporarily reduced grazing pressure, but a slightly more intensive use of birch forest resources and agriculture. In Abisko, Sweden, sustainable tourism has been found to be a good alternative, while in Iceland sheep grazing pressure must be reduced to allow birch regrowth in deforested areas. Tourism, in addition to traditional forestry and reindeer herding, may also be a good alternative for sustainable development in northern Finland. •

Short- and long-term fluctuations in animal populations in Lake Myvatn – a model for climatic and human impact on the ecosystem

An immense data set of the variability of the Lake Myvatn ecosystem in northern Iceland has been collected over the last 25 years. This unique long-term record of plants and animals makes this lake a useful model for assessing the climatic and human impact on a subarctic ecosystem. The time period is long enough to cover the variability associated with the population dynamics of animals and to allow comparison with climatic variables.

The highlight of the project is the publication of a special Lake Myvatn issue of *Aquatic Ecology* with the title: "Ecology of Lake Myvatn and the River Lax: Tem-

poral and Spatial Variation" edited by Árni Einarsson & Ramesh D. Gulati. This is a collection of scientific papers on the lake and its surroundings, focusing on the spatial and temporal aspects of its ecology. We now have a comprehensive view of the long-term fluctuations in the ecosystem and their dynamics in the lake. This enables us to assess the human impact on the ecosystem much more effectively than before.

We have been able to bring together a huge amount of data on the complex Lake Myvatn to evaluate the temporal variation in the biota on different time scales and to focus more on the spatial vari-

ation than has been possible before. We have been able to get a clear picture of the groundwater systems and how they are affected by volcanic and human activities. The role of the lake sediment in providing nutrients to the lake has been significantly clarified. Weather patterns have been analysed and the relation to the NAO (North Atlantic Oscillation) examined, indicating no directly observable influence of this large-scale weather pattern on the lake. The regular oscillations of the lake biota have also been described.

A major breakthrough is that the driving force behind the most prominent fluctuation has

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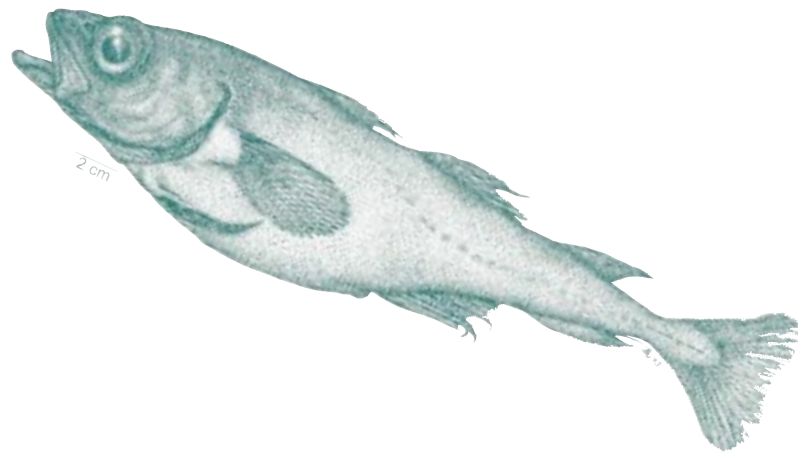


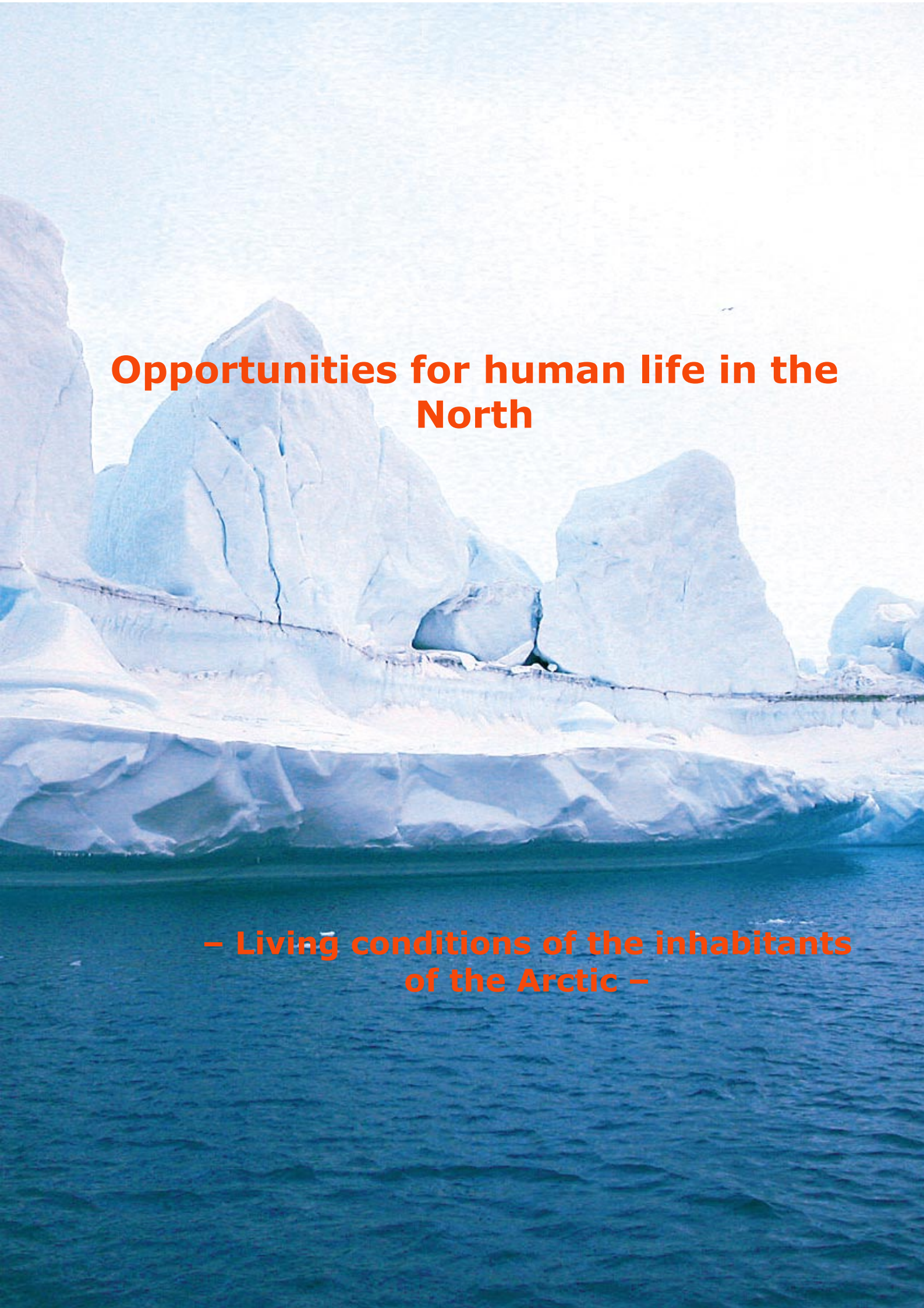
been identified as consumer-resource interaction (insect larvae interacting with their food resources) as opposed to predator-prey interaction (insect larvae falling prey to fish and predaceous insects). Hypotheses about causal

relationship with other species have been put forward. These will stimulate further research.

The project addresses the question of the effects of human impact on this lake of great natural variability. The results will back

up the decisions concerning the management of the lake, which has been a focus of debates over possible human impact during the past three decades. •



A large, jagged iceberg floats in a deep blue ocean under a clear sky. The iceberg has a prominent horizontal crack across its middle. The water is dark blue with some whitecaps, and the sky is a pale, clear blue.

Opportunities for human life in the North

– Living conditions of the inhabitants of the Arctic –

Survey of living conditions in the Arctic: Inuit, Sami and the indigenous peoples in Chukotka and on the Kola Peninsula

THE CONDITIONS
AFFECTING THE
INDIGENOUS
POPULATIONS IN THE
ARCTIC CHANGED
RAPIDLY DURING THE
PAST CENTURY

MANY INDIGENOUS
PEOPLE NOW MIX
TRADITIONAL ACTIVITIES
WITH PAID WORK

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The Inuit and Sami populations in Inuvialuit, Nunavut, Nunavik, Labrador, Greenland, Alaska, Chukotka, Norway, Sweden and Finland and on the Kola Peninsula share a number of economic, cultural and technological conditions. This is especially true of the traditional occupations on which these populations still base their livelihood, making themselves dependent on natural resources. However, the conditions affecting the indigenous populations in the Arctic changed rapidly during the past century. Many indigenous people now combine paid work with traditional activities, which has resulted in changes in their traditional lifestyles. This process has not always been successful. Indicators show higher unemployment, lower income levels, poorer health and more social problems among the Inuit and Sami than among the rest of the population in the countries in question. As a result, it is important from the perspectives of both policy planning and research to be able to document the present situation and any future changes in the living conditions in these areas.

However, research on the living conditions of the indigenous people in the Arctic has thus far been sporadic and, even at its best, dominated by regional interests. There is an obvious need for a comparative investigation of the individual living conditions in this area. It is very important to create a new research design, which would include both the development of a set of indicators of living conditions adapted to the spe-

cific economic and cultural characteristics of the indigenous peoples and a statistical method for sampling in the Arctic. The expected outcomes of the project are as follows: (1) To develop a new research design for comparative investigations of the living conditions of the Inuit and Sami populations in the Arctic. This will include the drawing up of a set of nominal and operationalised indicators of living conditions based on the theoretical literature, consultations with aboriginal organisations and public hearings. (2) To make a dynamic social analysis of the causal relations between different individual resources and between individual well-being and different political, economic, cultural and technological settings. (3) To map the living conditions among the Inuit and Sami in Greenland, Inuvialuit, Nunavut, Nunavik, Labrador, Alaska, Chukotka, Sweden, Norway and Finland and on the Kola Peninsula. This is expected to facilitate international and intranational comparisons of the living conditions on a number of dimensions. (4) To provide an improved ba-



sis for decision-making in relation to policy planning and implementation. (5) To establish an interdisciplinary network of researchers and research institutions engaged in living conditions research in the Arctic. (6) To involve both

indigenous and non-indigenous postdoc researchers, PhD candidates and undergraduates in the project. •

Life of the Norse in southwestern Greenland in 985-1500: Influence of environmental change on sustainability and farming conditions

The aim of the project was to investigate the sustainability and living and farming conditions of the Norse culture in southwestern Greenland by using the geological record. A special emphasis was placed on studying the possible impacts on the landscape caused by the use of land for grazing and agriculture under the marginal and changing conditions in Greenland. The Norse were farmers and Vikings living in Greenland from 985 AD onwards, until they disappeared from the area 500 years later.

Norse settlement

Icelandic sagas and historical and archaeological evidence indicate that a Norse colony was founded in southern Greenland by Eric the Red and other settlers from Iceland in 985 AD. The Norse disappeared from the settlement 500 years later. Despite a large number of studies performed onshore in the area of the eastern and western Norse settlements, the ultimate cause for the loss of the settlement has not yet been found. Explanations proposed for the dis-

appearance of the Norse population include climatic change, decline of shipping trade with Iceland and Europe, raids by European pirates, competition with immigrating Inuits and disease.

Medieval Icelandic sources report that, after the first period of colonisation, sea ice off southeastern Greenland significantly expanded, causing growing problems to Norse shipping between Iceland and Greenland. Numerous indications have been found on the northern hemisphere pointing to severe climate deterioration between about 1350 and 1850 AD (Little Ice Age), following the end of the Medieval Warm Period or Climatic Optimum (c. 900 – 1350 AD). As described by Dansgaard et al. (1989), the cold climate conditions revealed by the ice core records from central Greenland were characterised by dry and very stormy weather conditions. Stuiver et al. (1995) found in their study of the GISP2 Greenland ice core that the Little Ice Age cold conditions prevailed between ca. 1350 and 1800 AD, with the extremes of low temperature dated at 1720 AD. They dated the Medieval Climatic Optimum

A NORSE COLONY WAS
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RED FROM ICELAND 985
AD

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Changes in environment

Marginal areas, such as those in southern Greenland, can be crucially influenced by either extensive agricultural land use or even small-scale climatic changes or a combination of both. The present research project investigated the changes in the environment for the Norse colonisation of Greenland, covering the period from 985 to 1500 AD, and related these environmental changes to variations in the climatic conditions and the effects of human activities. A better understanding of the disappearance of the Norse from Greenland around 1500 is expected to be achieved by a detailed study of the coastal zone around Søndre Igaliko, a small but well established Norse community in the eastern settlement. •

peak at 975 AD, i.e. close to the time of the Norse settlement in southern Greenland. However, there has been no conclusive evidence for a causal link between the initiation of the Little Ice Age climate deterioration and the loss of both the western and eastern settlements of the Norse culture until now.

Development of methodologies for the evaluation of the socioeconomic and environmental consequences of mineral and energy industries in the Arctic and Subarctic

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The arctic environment has long been considered unspoiled and inexhaustible, but the consequences of trans-boundary contaminants and resource exploitation are becoming an increasing concern. An image of the arctic communities as hunters and trappers living in traditional interdependency with the environment makes way to a concept of a modernised society. There has been a boom in min-

eral and energy industries in the arctic regions during the last few decades. Industrial development has severely affected traditional living in many small settlements in the Arctic, e.g. in Arctic Canada, Arctic Russia and Alaska. Mineral and energy industries are on the agenda, but not yet in operation, in some other arctic regions, too.

As the Arctic Council and local commu-

nities give high priority to sustainable development, the need for knowledge concerning the possible consequences of mineral and energy industries has increased. Some of the environmental consequences of the extraction of minerals and gas in the unprotected arctic environment are covered by international programmes for environmental protection strategies. Meanwhile, the consequences concerning socioeconomic status, employment and social affairs are paid less attention. However, these are key factors in developing the visions of comprehensive sustainable development in the Arctic.

The project arranged a Nordic workshop and an international conference with wide Nordic participation with a focus on the development of methodologies for the evaluation of the socioeconomic and environmental consequences of mineral and energy industries in the Arctic. A very successful workshop was held at the Kola Science Centre, Apatity, Russia, on May 8 - 12, 2002. A total of 50 participants from the circumpolar world, including scientists from the major research centres with a northern focus, met for four days to discuss issues of common interest. The purpose of the joint NARP/NATO

workshop was to consider the consequences of mining activities and energy production in the Circumpolar North with special focus on methodologies for evaluating the long- and short-term socio-economic and environmental consequences of the activities. Based on comparative analyses of experiences from regions with different environmental, social, economic and political situations, the goal has been to outline a set of general recommendations regarding the preparation of future booms in mining and energy industries in the Arctic, as well as suggestions regarding appropriate environmental precautions and political interventions.

The workshop aimed at crossing scientific boundaries both between countries and between disciplines. A short-term goal was to create broader understanding to establish a network between scientists and to outline common goals and methodologies that may support the long-term process towards sustainable development in the Arctic. •



Forestry beyond the timberline: ecological and socio-economic factors affecting forestry in the context of rural development in the North Atlantic region

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The northern and northwestern periphery of Europe is known for its fisheries, scenic beauty and rather sparse human population. Forestry in this region is not usually counted as one of its main attributes. Nevertheless, considerable forestry activities are being carried out. Activities such as protection of the mountain birch woodlands of northern Scandinavia, protection of the forest remnants in Iceland, Scotland and Ireland and afforestation with a variety of goals in northern and coastal Norway and on the Atlantic islands, including Greenland. Research and extension play very important roles in all these endeavours. Afforestation and forestry are increasingly important factors in rural development in this region, and protection of natural forests and forest remnants are important from the viewpoints of both nature conservation and tourism.

A successful workshop, "The Forestry Beyond the Timberline", was held in Akureyri, Iceland, on June 27-30, 2000. It was attended by 54 participants



from 13 countries. A total of 27 papers and 10 posters were presented. This was the largest scientific conference on forestry held in Iceland to date. Various papers presented may have significance for political decision-making. The results of the workshop as a whole can be summed up as follows: Forests and forestry are no less important to people living "beyond the timberline" in the North Atlantic region than to people living in forested countries. Apart from being a source of wood and other forest products, forests and woodlands in this region serve

important functions for conservation, recreation and shelter. Building up a forest resource through afforestation can benefit rural communities in many ways and aid in the sustainable development of those communities. The proceedings were published as a special issue of the "Skógræktarriti" (annals of the Icelandic Forestry Association). •

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NARP Highlights

Nordic Arctic Research Programme – Rapid Changes in the Arctic

Nordic Council of Ministers



The aim of the Nordic Arctic Research Programme (NARP) was to enhance Nordic competence and research co-operation in three priority areas: Natural Processes - Land, Sea and Atmosphere; Biological Diversity and Environmental Threats in the Arctic; and Living Conditions of the Inhabitants of the Arctic.

In this publication, we introduce the programme and some research results as a series of short highlights provided by the project coordinators, to illustrate the diversity of the accomplishments by the Nordic Arctic scientific community. Outstanding work on a variety of Arctic issues has been done throughout the programme. The Nordic Arctic Research Programme supported especially networking and mobility between several research groups. A great number of young students have greatly benefited from their study visits in Nordic laboratories, and there is an urgent need to find funding for further collaboration. Also, co-operation with researchers from the Faroe Islands, Greenland and Iceland has increased during the programme. The programme included 63 projects focusing equally on the above-mentioned three priority areas.

It has become clear during the course of the Nordic Arctic Research Programme that there is still an urgent need for multidisciplinary scientific Arctic studies in the future. Especially the trends and amplitudes of environmental change in the Arctic region are still poorly recorded, and many feedback processes of change are not fully understood. The rapidly changing socio-economic conditions in the Arctic require further scientific attention. More scientists and especially young talented people should be involved in Arctic science in the future.

The programme was carried out during the period 1999-2003 and finalised in 2004. The annual budget was 6.2 million DKK, amounting to a total of 31 million. The programme hence provided a particularly good opportunity for Nordic cooperation and networking of research. The secretariat of the programme worked in Thule Institute at the University of Oulu.

More information is available at <http://thule oulu.fi>