

2009

POLAR RESEARCH IN TROMSØ



EDITORIAL

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RETROSPECTIVE

IN BRIEF

RECENT DOCTORATES

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POLARMILJØSENTERET



INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET



Economic unrest?

For much of the world, 2009 was a year of economic turbulence. The stock market wobbled, businesses and financial institutions faced bankruptcy, interest rates plummeted and unemployment shot sky-high. Tromsø is not immune to the economic situation, yet the city has come through the year relatively unscathed. Clearly Norway's oil reserves get some credit, but part of the stability must be attributed to the Norwegian Government's High North Strategy. First presented in 2006, the strategy aims to create sustainable growth and development through intensified international co-operation around the use of natural resources, environmental management, and research. Three years on, the High North remains at the top of the political agenda.

In March 2009 Prime Minister Jens Stoltenberg visited Tromsø, accompanied by the ministers of Finance, Fisheries, Transport and Foreign Affairs, to present the next step in the High North Strategy: *New Building Blocks in the North*. This document defines seven priority areas and number one on the list is "to develop knowledge about climate and the environment in the High North".

Three of the goals have particular relevance for the research community in Tromsø: to map the diversity of the seabed; to build a new ice-class research vessel; and to establish a Cen-

tre for Climate and the Environment, based in Tromsø itself. An integral part of this last initiative is the Centre for Ice, Climate and Ecosystems, ICE, presented on page 14. ICE was officially opened in March by Erik Solheim, the Minister of the Environment and International Development.

Together with the High North Strategy, *New Building Blocks in the North* charts out a course for the next 10 to 15 years. The world economy may be on a roller-coaster ride, but this long-term commitment bodes well for Tromsø's future as a hub of polar research.

A call for action

As this issue of *Polar Research in Tromsø* goes to press, scientists and world leaders are gathered in Copenhagen for the United Nations Climate Change Conference, COP15. And they are in the public eye. The conference is being followed closely all around the world – by people concerned about impacts on the environment, people worried for their children's future, people whose very livelihood is threatened. Droughts and floods, extreme weather conditions, and rising sea levels will put even greater pressure on people who are already struggling to survive.

And then there are the expected effects on ice and snow. Ironically, it is in the coldest parts of the Earth that global warming is "hottest". Climate models predict that warming trends

will be seen earliest near the poles. Norway has a unique perspective – being the only nation with territorial claims in both polar regions – and Norwegian scientists have contributed crucial monitoring data that appear to confirm these warming trends. Indeed, many experts believe we are already beginning to see the first consequences of global warming, particularly in the Arctic: shorter winters, retreating glaciers, thinning sea ice.

The Norwegian Polar Institute and ICE have been instrumental in compiling current knowledge on the cryosphere: snow, sea ice, glaciers, the Antarctic and Greenland Ice Sheets, permafrost and river/lake ice. The result is a 95-page report targeting decision-makers, journalists and other interested nonscientists. This work was commissioned for COP15 by Nobel Laureate Al Gore and Norwegian Minister of Foreign Affairs Jonas Gahr Støre, who will soon present the report, entitled *Melting Snow and Ice: a Call for Action*. Will their voices be heard amidst the clamour in Copenhagen? Will the call be answered? We do not know yet whether COP15 will represent a step forward or a disappointment, whether it will end in consensus or discord. All we know is that whatever the outcome, we must continue to move onward. And we are certain that research done in Tromsø will help light the path.

Polar Research in Tromsø

Polar Research in Tromsø is published once a year by the University of Tromsø (UiT), the Norwegian Polar Institute (NPI), the Tromsø branch of the Institute of Marine Research (IMR) and the Polar Environmental Centre (POMI), Tromsø, Norway. Its aim is to describe all manner of education and research in polar (chiefly Arctic) studies carried out during the past year at these institutions and at other research institutes and companies in the Tromsø area with which they have close ties.

It is sent on request and free of charge to all persons who are interested in polar studies.

Editor

Janet Holmén
c/o Norwegian Polar Institute
Polar Environmental Centre
N-9296 Tromsø
e-mail: postmottak@npolar.no

Sub-editors

For the University of Tromsø

Mona Solbakk
telephone: +47 77 64 49 84
e-mail: mona.solbakk@uit.no
web: uit.no

For the Polar Environmental Centre

Are Johnsen
telephone: +47 77 75 02 02
e-mail: are.johnsen@npolar.no
web: www.polarenvironment.no

For the Norwegian Polar Institute

Gunn Sissel Jaklin
telephone: +47 77 75 06 40
e-mail: jaklin@npolar.no
web: www.npolar.no

For the Institute of Marine Research

Vera Helene Lund
telephone: +47 77 60 97 14
e-mail: vera.helene.lund@imr.no
web: www.imr.no

Print run: 3000 copies
Layout: Bjørn Hatteng, UiT
Trykk: HSL trykkeriet, UiT
Printed on eco-friendly paper

Front page photographs:
Kim Holmén (NPI)

Shrimp, the marine equivalent of the “canary in the mineshaft”



Pandalus borealis is sensitive to temperature change. Photo: Rudi Caeyers

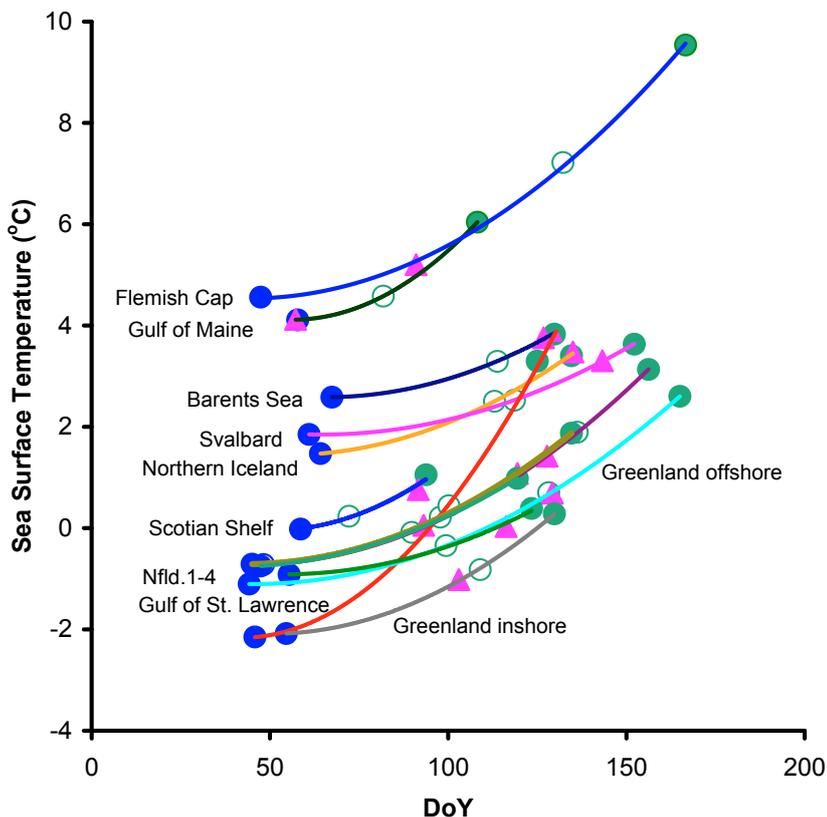
Michaela Aschan

michaela.aschan@uit.no
Norwegian College of Fishery Science
University of Tromsø

Peter Koeller

Peter.Koeller@dfo-mpo.gc.ca
Bedford Institute of Oceanography
Fisheries and Oceans Canada

Canaries are especially sensitive to methane and carbon monoxide. They were used in early coal mines as a method of gas detection – as long as the canary kept singing, the miners knew their air supply was still safe.



The northern shrimp, *Pandalus borealis*, is one of the largest fisheries in the world exceeding an annual catch of 400 000 tonnes, currently worth 2.5 billion NOK. The shrimp also sits in the middle of the North Atlantic Ocean's food chain, between the small organisms that it eats, like phytoplankton, zooplankton and benthos, and predators that eat it, like cod and other commercially important finfish. As a result, it is the marine equivalent of the “canary in the mineshaft”, sensitive to various types of changes in the ecosystem, often even before they are generally evident.

When cod stocks collapsed in the early 1990s, shrimp populations throughout the northwest Atlantic exploded. Although much of this was eventually attributed to the decrease in predation by fish on shrimp, there is also an environmental component to the story: the late 1980s and early 1990s were years of exceptionally cold water in the North Atlantic and shrimp stocks increase and thrive during periods of cold water. This makes sense considering *Pandalus borealis*' northern circumpolar distribution, but the actual cause of its sensitivity to changing water temperatures was not understood until now.

As part of a multi-disciplinary, international team of researchers we recently published an article in the journal *Science*, reporting that across the entire north Atlantic, from Cape Cod (USA) to Svalbard (Norway) well past the Arctic Circle, northern shrimp eggs hatch on average within days of the annual spring phytoplankton bloom.

This synchronisation is remarkable in itself, but even more surprising when one takes into consideration that the timing of the spring bloom varies greatly over the shrimp's range. This is due in part to latitudinal differences in the solar cycle – gener-

Sea-surface temperatures for each study area at their annual minimum (solid blue circles), at phytoplankton bloom initiation (open green circles), at peak chlorophyll-a concentration (solid green circles), and at 50% hatch times (pink triangles) (*Science* 2009, 324:791-793).

ally spring comes later as one moves poleward. Moreover, the time it takes shrimp eggs to develop into young shrimp (larvae) and hatch depends on local bottom water temperatures. In the warm waters off Cape Cod, the eggs take only 6 months to hatch, but off Northern Svalbard and Northern Iceland it takes almost a year.

If the larvae are to emerge during the spring bloom when food is abundant, their parents must mate at just the right time during the previous year, taking into account local differences in bottom water temperatures as well as the solar cycle. The shrimp's reproductive cycle has adapted and evolved to accommodate local average conditions, including bottom temperature and spring bloom times, so that the hatch and the bloom approximately coincide. Unfortunately,

this strategy for improving the chances of larval survival has its pros and cons.

As long as the bottom water remains cold, egg development times are long and eggs hatch late, close to both the phytoplankton bloom and the seasonal warming of the surface waters where the larvae live – ideal conditions for survival. On the other hand, if bottom water temperatures rise due to global warming, this may eventually result in the eggs hatching too early, leaving the shrimp larvae unable to take advantage of the abundance of food that becomes available during the spring bloom.

To further complicate the picture, global warming of surface waters may actually change the timing of the spring bloom. This could also perturb the match between hatching time

and peak food abundance, a coupling the shrimp have been cultivating over eons of evolutionary time. A decrease in shrimp abundance may be the first sign of such fundamental changes to the marine ecosystem.

Essential data on shrimp biology were provided for this research by the national fisheries research programs of major shrimp fishing nations, including Norway, Iceland, Greenland, Canada and the USA. The study would not have been possible without the availability of satellite ocean colour (phytoplankton abundance) data, collected and analysed over the last ten years by the remote-sensing team at the Bedford Institute, led by Trevor Platt (now at the Plymouth Marine Laboratory) and funded by the Canadian Space Agency.

Rapid melting of sea ice explained by melt ponds?

Christina Alsvik Pedersen

christina.pedersen@npolar.no

Jan-Gunnar Winther

winther@npolar.no

Norwegian Polar Institute, Polar Environmental Centre, Tromsø

Erich Roeckner

erich.roeckner@zmaw.de

Max Planck Institute for Meteorology, Hamburg, Germany

Mikael Lüthje

mikael.luthje@iku.sintef.no

Sintef Petroleum Research, Stavanger, Norway

The mean temperature in the Arctic has risen twice as fast as the global mean temperature in the past 100 years, resulting in a substantial loss of sea ice. The decline in the minimum extent of the Arctic sea ice has attracted particular attention. All the climate models used as a basis for the Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) show a decline in sea-ice extent, but none of them show the dramatic decline we have witnessed in the last few years. One reason may be shortcomings in the description of the energy balance in current global climate models. Recently we have developed a new and physically more correct de-



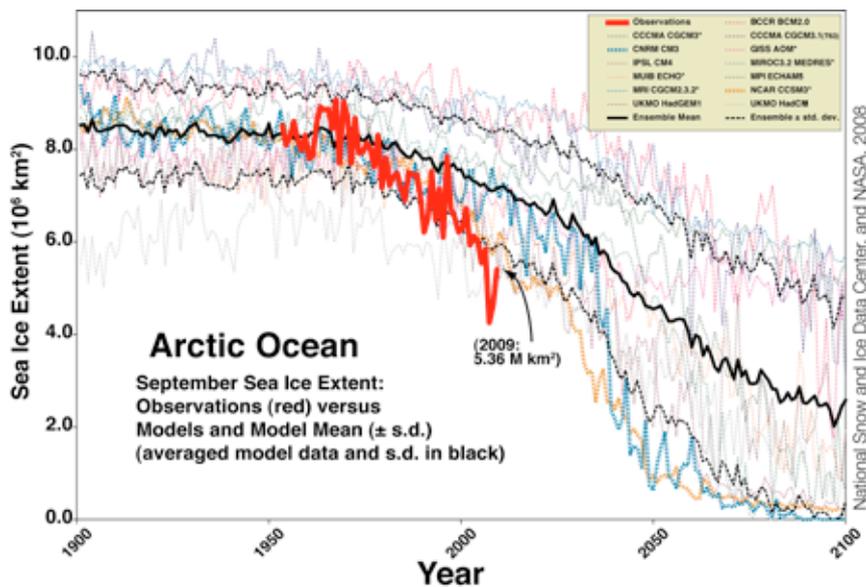
The refrozen melt pond in the foreground is clearly darker than the surrounding snow, and absorbs much more of the incoming sunlight. Photo: Sebastian Gerland (NPI)

scription of the sea ice albedo in the general circulation model ECHAM5.

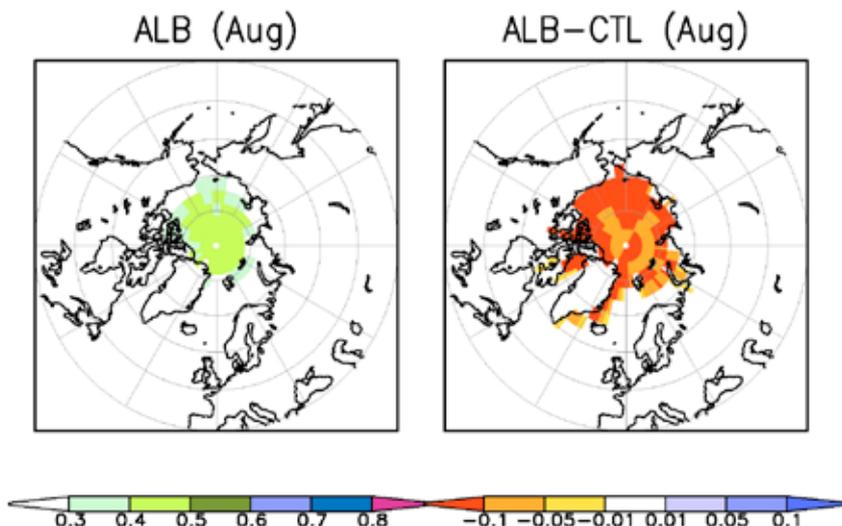
The albedo of a surface is the ratio of reflected to incoming solar radiation. White snow surfaces have a high albedo (up to 85-90%), whereas that of open water is low (about 7%). This means that sea ice is particularly sensitive to a moderate temperature rise: a warmer climate will melt some

of the ice and expose larger areas of open water, resulting in more of the incoming sunlight (heat) being absorbed, which again leads to further warming. This amplifies the warming and creates a positive feedback.

Traditionally, climate models have treated high-latitude cryospheric processes quite crudely, and previous studies have shown that today's mod-



Arctic sea ice extent as shown by observations (thick red line) and by 13 of the models used by the IPCC (bold black line shows the mean of all the models, and the dotted black lines the standard deviation). Updated from Stroeve et al., *Geophys. Res. Lett.* 34 (L09501), 2007



Modelling of sea ice albedo in August (50-year average) using the climate model ECHAM5 with the new algorithm (ALB, left), and the difference between the sea ice albedo given by the new and old algorithms (ALB-CTL, right). Left panel: The new algorithm gives that only about 40-50% of the incoming solar radiation is reflected in August. Right panel: This is a reduction of 5-15% compared to the old algorithm. Figure from Pedersen et al., *J. Geophys. Res.* 114 (D08101), 2009

els are unable to capture the annual cycle of sea-ice albedo, particularly in summer, when the models overestimate the albedo. Our new description, or algorithm, of sea ice albedo distinguishes between snow-covered sea ice, bare sea ice, melt ponds and open water. This is the first time a physical description of melt ponds has been explicitly included in a global climate model.

In spring and summer, the snow and the upper surface of the sea ice melt, and the melt water gradually accumulates in melt ponds on the

ice. These melt ponds substantially reduce the albedo of the sea ice, and absorb two to three times as much solar radiation as snow-free thick sea ice. Earlier studies have shown that the proportion of the sea ice covered by melt ponds in summer varies widely, from 5% to 80%, depending on the roughness of the ice surface, the snow depth, the ice type, the time of year and the geographical location. The spatial distribution depends mainly on the topography of the ice. First-year ice is smoother than multiyear ice, so that melt ponds on first-year

ice are usually shallower, but cover larger areas. Multiyear ice is rougher, and melt ponds form in depressions, where they tend to be smaller, deeper and more numerous.

In a paper published in the *Journal of Geophysical Research*, we present the new sea-ice albedo description. The ECHAM5 climate model was used to compare our new albedo algorithm with the original algorithm (which only used temperature-dependent albedo) in terms of their ability to simulate climate and sea ice in the Arctic. The new algorithm simulates the annual cycle of sea ice albedo more realistically, showing a decline in albedo both in winter (as the snow ages) and in summer (as melt ponds form). The new algorithm also performs well in modelling the distribution of melt ponds: the timing of their formation and their extent agree well with observations. Simulations showed some melt ponds forming as early as May, and some persisting until September. Also, the albedo reduction arising because of shallow ponds on the first-year ice proved to be larger than that arising from the deeper ponds on multiyear ice, because the ponds covered larger areas on the first-year ice. In fact, in July, melt ponds covered 77% of the total area of first-year ice, but only 20% of the multiyear ice.

The new algorithm had most effect on the results for the summer months; the albedo in August was found to be 23% lower than in simulations using the original algorithm. The lower sea ice albedo leads to thinner sea ice, and smaller ice extent and volume, but with spatial and temporal variations. The reduction in extent was largest (8%) in August and September. On average, the sea ice volume was 10% lower than indicated by the original algorithm.

The new algorithm represents an advance in our ability to model the current record rate of sea ice melt in the Arctic. Today we see that more and more of the rough old multiyear sea ice is being replaced by the smooth young first-year sea ice, and our simulations show that melt ponds may play an even more important role in ice melt in the Arctic in the years to come.

The Nenets people in the Russian Arctic monitor their changing environment

Winfried Dallmann

dallmann@npolar.no

Norwegian Polar Institute, Polar Environmental Centre, Tromsø

The Nenets Autonomous Okrug (NAO) in northwestern Russia is home to approximately 8000 Nenets and 3000 Izhma-Komi indigenous people. Many of them depend directly or indirectly on reindeer husbandry, fishing and hunting for their livelihood. In the past, reindeer pastures covered almost all of the territory. Now, however, large tracts of land have been degraded by oil prospecting and production, or have become difficult to access across oil pipelines. Lakes and rivers are increasingly polluted.

Indigenous people in general have a large capacity to adapt to environmental changes. But areas to escape to are getting fewer and smaller, while increasing portions of the land become useless for traditional occupations. In addition, the unemployment rate among indigenous people is high. Individuals with more advanced education often leave the area. Life expectancy is extremely low – in the forties – because of both poor access to medical care and abuse of alcohol. These and other factors go hand in hand with a general disintegration of indigenous society.

The lure of oil further exacerbates the problem. An uncontrolled situation has developed around oil and gas

exploitation in many parts of the NAO, where some oil companies are accused of grave violations of ecological standards and Russian legislation. Numerous oil spillages and other degradations of the upper soil layers occur periodically in the tundra, inflicting damage on the Arctic natural environment, which is the basis for the livelihood of the indigenous people.

Legal norms for implementation of federal laws governing land ownership and land use are still absent in the NAO. Land can be allotted for industrial and resource-extraction purposes, while the former users – the indigenous people – receive inadequate financial compensations. Negotiation processes result in agreements, where the amount of financial compensation is regulated. A major problem for social equality and welfare is the fact that these agreements are often confidential.

It is important to realise that environmental map data in Russia are available to the public only to a very limited extent. Further, a complete overview is lacking, and the situation changes quickly. A continually maintained map database would be an indispensable tool to track development.

The International Polar Year project MODIL-NAO (Monitoring of Development of Traditional Indigenous Land Use Areas in the Nenets Autonomous Okrug, NW Russia) is a

cooperation between the Norwegian Polar Institute and the Association of Nenets People Yasavey. The principal objective is to give the indigenous population of the NAO a tool – a GIS map database – to promote their interests in an area of intensive industrial development, carefully balancing between the need for detailed information and what is lawful to publish in Russia.

A major source of data for the project is a questionnaire campaign directed towards traditional land users, mainly reindeer herders. Topics include all spheres of their living, their traditional occupations, their socio-economic situation, and the condition of their natural environment. Satellite images in GoogleEarth were used to monitor visible, physical damage of the tundra. These data are combined with publicly available data in a GIS database. The database was developed in the ArcGIS programme, but is being transferred for publishing to a GoogleEarth-based system, which does not require special skills or software for the users.

It is hoped that the database will be used by the indigenous people to make informed decisions about their future, to discuss land use plans with representatives of the government authorities, to negotiate compensations, and so on. It is also hoped that the representatives of the Nenets people will have the resources to maintain



Reindeer are used for transportation during nomadic migrations. Chernaya area, northeastern NAO. Deeply eroded vehicle tracks are a frequent feature in many parts of the Nenets tundra. Varandey area, northeastern NAO. Photos: Zoia Vylka Ravna, 2008 (left), Association of Nenets People Yasavey, 2003 (right)

and further develop the database in the future.

By the end of 2009 the bilingual, interactive database is intended to be posted on the Internet – accessible for everybody who has downloaded GoogleEarth. The English and Russian language versions of the project report will be available electronically at the same time. Printed versions will hopefully be available later in 2010.

Project website:

<http://npolar.no/ipy-nenets>

Degraded tundra is not confined to drilling sites and pipelines. There seem to be no effective restrictions against using heavy vehicles on unfrozen ground. Varandey area, northeastern NAO. Photo: Association of Nenets People Yasavey, 2003



Omega-3 fatty acids in Arctic marine food chains

Stig Falk-Petersen

stig.falk.petersen@npolar.no

Haakon Hop

haakon.hop@npolar.no

Norwegian Polar Institute, Polar Environmental Centre, Tromsø

Jørgen Berge

jorgen.berge@unis.no

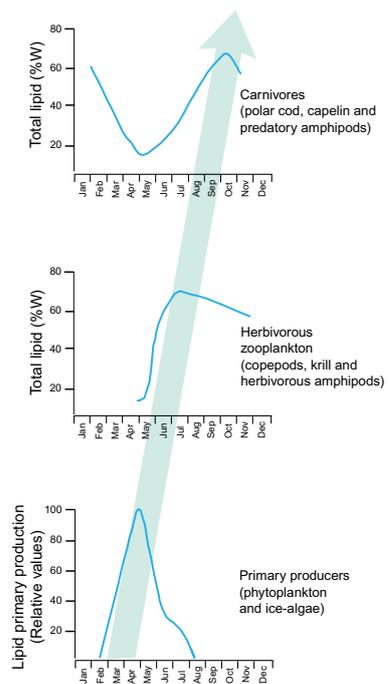
University Centre in Svalbard, Longyearbyen

Omega-3 fatty acids are a vital building block in human cells and essential in many important physiological processes, e.g. memory and vision. At the Norwegian Polar Institute we have over the last years studied production and transfer of omega-3 fatty acids from phytoplankton and ice algae through intermediate trophic levels of zooplankton and fish to seals and seabirds.

Polyunsaturated fatty acids (PUFAs), with the most widely-known omega-3 fatty acids as prominent representatives, have been shown to play a key role not only in aquatic ecosystems but also for human health, affecting reproduction, growth and physiology. Omega-3 fatty acids are known to prevent cardiovascular diseases, improve memory and concentration, and counteract depression, in addition to more cosmetic effects

such as preventing skin ageing and protecting the skin against UV radiation. Omega-3 has become a valuable commercial product worldwide, and today the market for omega-3 oils is growing by 25% annually, with a production of 50 000 tonnes per year. Traditionally, omega-3 was extracted from the liver of cod fish and pelagic fish species such as capelin and herring. Today, krill and *Calanus* copepods are also commercially harvested, and one of the most valuable products derived from them is omega-3 rich oils.

The essential omega-3 fatty acids are produced exclusively by marine algae, and the lipid-driven energy flux in polar marine ecosystems ensures that these essential components are transported efficiently through the food chain. Towards high latitudes, the annual period of primary production becomes shorter due to the strong seasonality of incoming solar radiation and ice cover. The omega-3 fatty acids produced by phytoplankton and ice algae during the short Arctic summer are the source of all omega-3 that is transported up the food chains to zooplankton, fish and seals and finally harvested by fishers and hunters. To gain further insight into the role and transfer of omega-3 fatty acids in po-



The omega-3 fatty acids produced by ice algae and phytoplankton during the blooms are transferred through the food chain during the Arctic summer and autumn (After Falk-Petersen et al. 1990. In: *Trophic relationships in the marine environment*. Barnes and Gibson, eds. Scotl. Univ. Press, Aberdeen. pp 315-333).

lar marine ecosystems, it is crucial to understand triggers that influence the timing of omega-3 fatty acid production.

Our work has focused on the herbivorous copepod *Calanus glacialis*,



Collecting ice algae under sea ice in Rijpfjorden. Photo: Jørgen Berge (UNIS)
Dinner outside "Bjørnehiet" during the field campaign in Rijpfjorden in late Spring. Photo: Janne Søreide (UNIS)



one of the most important species in Arctic shelf seas, accounting for up to 70% of the zooplankton biomass. This copepod is perfectly adapted to current ice conditions in the Arctic Ocean. We have documented that *C. glacialis* utilises two distinct peaks in omega-3 production, one associated with sea ice during the ice algal bloom

and the second in open waters during the phytoplankton bloom. Reductions in ice extent will affect the first important part of this production, when the copepods feed on ice algae.

The scientific project development, planning and performance of extensive field work, laboratory and in situ experiments, and chemi-

cal analyses have been carried out by a group of young scientists – all of them women – from the Norwegian Polar Institute, the University Centre in Svalbard, the University of Tromsø and Université Pierre et Marie Curie, in France. Drs. Eva Leu and Janne E. Søreide have been the driving forces behind the science, studying the timing of the ice algal bloom and its relationship to reproduction of the key grazer, *Calanus glacialis*, in Arctic shelf seas. They played a leading role in the field campaign under extremely harsh conditions in Rijpfjorden, one of Svalbard's northernmost fjords, facing the Arctic Ocean. Anette Wold carried out the field sampling on the ice in the Canadian Arctic on board the Canadian research ice-breaker *CCGS Amundsen*, at temperatures down to minus 30°C. Margaux Noyon and Fanny Narcy from France studied the lipid dynamics and omega-3 levels in carnivorous zooplankton in Kongsfjorden, Svalbard. Three masters students, Marte Lundberg, Charlotte Gannefors, and Iris Jæger, studied the transfer of omega-3 to ctenophores, winged snails, and seabirds.

The study of the role of omega-3 in Arctic marine food chains has been carried out within the framework of three large research projects, MariClim, CLEOPATRA and Ice-edge project (<http://mariclim.npolar.no>; www.iceedge.no). All these projects are part of the ARCTOS research network (www.arctosresearch.net). The project was funded by the Research Council of Norway and Statoil.

Best practices in ecosystem-based ocean management

Alf Håkon Hoel

ahhoel@gmail.com

Department of Sociology,
Political Science and Community
Planning, University of Tromsø, and
Environmental Management Section,
Norwegian Polar Institute, Polar
Environmental Centre, Tromsø

The need to manage the marine environment and its natural resources in an integrated manner is now broadly recognised and accepted.

A number of international agreements oblige countries to implement ecosystem-based management of their oceans, to ensure the sustainable development and conservation

of marine ecosystems as a whole. While there is a clear scientific rationale underscoring the need for integrated ocean management, it is not clear how this is to be accomplished. Many countries are in the process of developing their ocean management policies, but there is no common international standard for how this is to

be done, nor is there an agreed definition of what “ecosystem-based ocean management” means in practice.

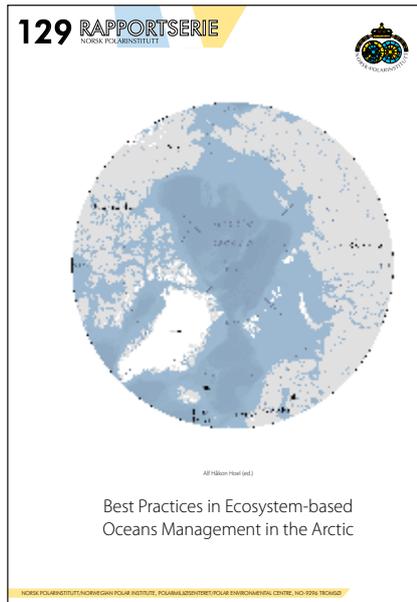
As part of the Norwegian chairmanship of the Arctic Council 2007-2009, the Best Practices in Ecosystem-based Ocean Management project was initiated to address the issue of how countries implement ecosystem-based ocean management. An important objective was to identify “best practices” or useful instruments and work methods in this regard.

The project involved scientists and public officials from Russia, Canada, USA, Denmark/Greenland, Iceland, Norway and Finland, as well as from the Permanent Participants of the Arctic Council (indigenous peoples). It resulted in a series of case studies addressing a predefined set of questions. The final report presents these case studies, along with a brief introduction and a chapter describing the issues from the perspective of indigenous peoples. One important finding is that there are substantial differences among the Arctic countries in terms of the nature of the marine ecosystems, the economic activities, the institutional arrangements for ocean management, and the scientific basis for this management. Therefore, one size does not fit all. Management systems and practices have to be tailored to the particular circumstances in each country and region.

If there are differences, there are also commonalities. Some core elements should always form a part of a country’s ecosystem-based ocean management. These include the definition of the geographical scope of ecosystems by ecological criteria, the application of the best available scientific knowledge to understand ecosystem interactions, and the assessment of cumulative impacts of different sectors on the ecosystem, rather than single-species, sectoral approaches.

Six “best practices” have been identified:

1) Flexible application of ecosystem-based ocean management: The Arctic is a diverse region. Therefore, differences in circumstances and contexts have to be taken into con-



Map: Anders Skoglund, Graphic design: Jan Roald, Norwegian Polar Institute

sideration. Ecosystem-based ocean management is context-sensitive, there exists no one, single method for ecosystem-based management. Also, ecosystem-based management is a work in progress and should be considered as a process rather than an end state.

2) Integrated and science-based decision-making: Increased communication and exchanges of scientific knowledge among both states and sectors in society are key components of ecosystem-based management. Scientific knowledge often needs to be synthesised and communicated for the purpose of ecosystem-based ocean management. Good lines of communication between managers, resource users, and the general public are necessary to foster mutual understanding and recognition of shared interests.

3) National commitment: A national commitment to conservation and sustainable use of the oceans and their resources is necessary. A “roadmap”, management plan or national action plan for addressing priorities in ocean management is critical in this regard. An important element in implementation is

legislation to provide government strategic directions.

4) Area-based approaches and transboundary perspectives: The identification of management units within ecosystems should be based on ecological criteria, as ecosystem-based management requires specific geographical units at various scales. In shared ecosystems, cooperation could occur through existing regional management bodies or new collaborative efforts focused on individual ecosystems.

5) Stakeholder participation: To build understanding and foster development of knowledge, stakeholder consultation is important. Also, stakeholder participation can encourage and contribute to compliance with conservation measures through education and enforcement.

6) Adaptive management: Effective management of ecosystems requires that management strategies change in response to changing circumstances. This is especially important in view of the accelerating effects of climate change on marine ecosystems.

The case studies were collected in a report prepared for the Arctic Council Ministerial meeting 29 April 2009. The best practices section of the report provided the basis for a set of “Observed best practices in ecosystem-based oceans management”, which were endorsed by the Arctic Council. It was also decided to continue work under the auspices of the Arctic Council relating to ecosystem-based ocean management. Several projects under the Protection of the Arctic Marine Environment (PAME) and Sustainable Development Working Group (SDWG) contribute to this.

Foreign tourists' landscape perceptions and preferences in Lofoten and Vesterålen, northern Norway

Jens Kr. Steen Jacobsen

jsj@toi.no

Aslak Fyhri

af@toi.no

Institute of Transport Economics, Oslo

Hans Tømmervik

hans.tommervik@nina.no

Norwegian Institute for Nature

Research, Polar Environmental Centre,

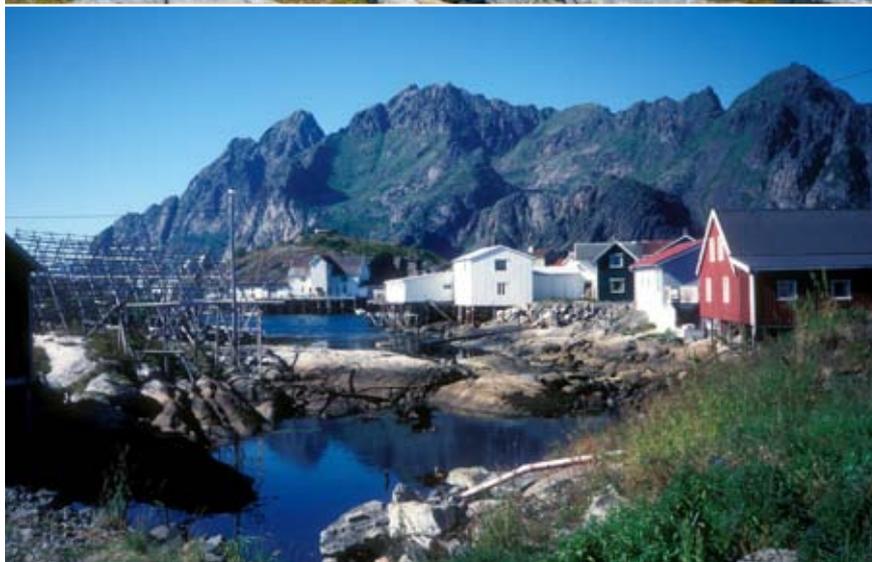
Tromsø

North-Norwegian coastal landscapes are changing. Some of these alterations are physical, caused by changes in climate, agricultural policy, industry and housing development. But some are less tangible, such as alterations in perceptions, resulting from transformation of local ways of life and dissemination of romantic attitudes among both tourists and locals. One of the most significant visual alterations – in Northern Norway and elsewhere – is the general re-growth and overgrowth of former farmlands. Encroaching vegetation may obscure vistas for sightseers, conceal cultural remains, decrease biodiversity, reduce the local population's access to valued areas, and probably also cause some locations to lose their "placeness". Landscapes always possess character that derives from how and why people know and use them. In Northern Norway, these could be farmland, bird sanctuaries, cloudberry moors, one's native district, and the sites visited on family outdoor excursions and holiday trips. Often, ideas of local identity are imparted by landscape features: cultural markers such as distinctive vernacular architecture and other tangible heritage.

Top: Foreign tourists expressed the most positive opinions about rugged, rocky coasts. Photo: Hans Tømmervik (Norwegian Institute for Nature Research)

Middle: Picturesque fishing villages were also popular scenes. Photo: Jens Kr. Steen Jacobsen (Institute of Transport Economics)

Bottom: Tourists did not find spruce plantations particularly attractive. Photo: Jens Kr. Steen Jacobsen (Institute of Transport Economics)



Many of the most appealing and dramatic sceneries around the world also constitute the livelihood of tourism-related industries with a finite – and dwindling – number of destinations at their disposal. Among such precious vistas are parts of the archipelagos of Lofoten and Vesterålen, the case area of “TOPCOAST”, a multidisciplinary study funded by the Research Council of Norway. Parts of this project responded to a deficiency of academic research on landscape perceptions among tourists. The main objective was to explore international tourists’ landscape perceptions in Vesterålen and Lofoten, focusing on three different concepts thought to be important for tourists’ landscape preferences: typicality, vegetation lushness, and degree of human influence.

Photo-based interviews and sorting procedures were employed among a sample of international tourists while they were visiting the case region. Although general studies of landscape perception and scenic beauty represent some well-established traditions, very few academic studies of tourists’ perceptions of and preferences for agriculturally related landscapes have been conducted. Even fewer studies encompassing

visualisations of landscapes have been conducted through representational options such as photographs. In most research, landscape quality is indicated by the human observers’ expressions of preference (choice, like/dislike) or judgments and ratings of visual aesthetic quality – for instance scenic beauty. As basis for the sorting procedures, twelve colour photographs were employed, all presenting landscapes that tourists are likely to encounter if they travel along or in the vicinities of the route of the express coastal liner (Hurtigruten) through the archipelagos of Lofoten and Vesterålen. Participants were given several sorting tasks (free sort, typicality, lushness, and preference) and were asked to comment on their impressions of the pictured landscapes, thus providing both quantitative and categorical data. Data were then subjected to multidimensional scaling analysis.

The most preferred landscape was a barren coastal rock landscape, followed by fishing hamlets and deserted farmland dominated by meadow buttercup (*Ranunculus acris*), cow-parsley (*Anthriscus sylvestris*), and rosebay willowherb (*Chamaenerion angustifolium*). The least preferred landscapes were abandoned meadows covered

with tufted-hairgrass (*Deschampsia cespitosa*) and coastline hillsides with spruce plantations. It should be mentioned that the area of forested land in the study area increased by more than 30% during the period 1985–2007, mostly due to reduction in cultivation, grazing and forestry. Preference ratings did not unequivocally support previous findings that lush vegetation and little human influence are important aesthetic qualities. On the other hand, there is an indication that abandoned farmland and encroaching forests in coastal landscapes only play a minor role for foreign tourists. Visitors from abroad appear to appreciate mountains, barren coastal rocks and fishing hamlets more than an active agricultural landscape. The findings emphasise the need for taking into consideration typicality of settings in future landscape research.

For further reading:

Fyhri A, Steen Jacobsen JK, Tømmervik H. Tourists’ landscape perceptions and preferences in a Scandinavian coastal region. *Landscape and Urban Planning* 2009, 91:202–211.

East Antarctic snow accumulation changes

Helgard Anshütz

helgard.anschuetz@npolar.no

Elisabeth Isaksson

elisabeth.isaksson@npolar.no

Jan-Gunnar Winther

winther@npolar.no

Norwegian Polar Institute, Polar Environmental Centre, Tromsø

Karsten Müller

karsten.mueller@geo.uio.no

Institute of Geology, University of Oslo, Oslo

Mary Albert

Mary.R.Albert@usace.army.mil

Thayer School of Engineering, Dartmouth, New Hampshire, USA

Despite modern satellite techniques and concerted research efforts, Antarctica’s mass balance is still not entirely certain today and vast parts of

the East Antarctic ice sheet are not covered by ground-based measurements. Yet knowledge of the mass balance and the variability of snow accumulation rates in Antarctica is crucial for understanding processes in the climate system and for estimation of future sea-level change.

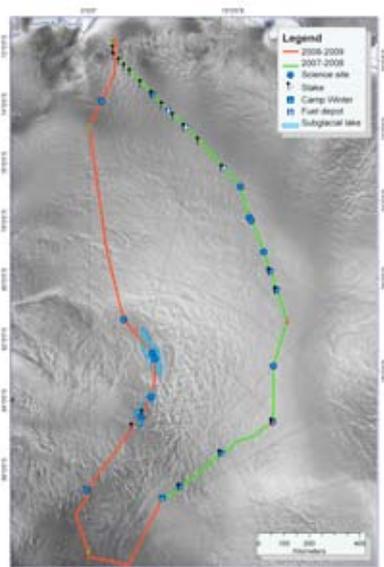
The Norwegian–US Scientific Traverse through East Antarctica is dedicated to closing some of these data gaps by contributing significant field data and assessing the spatio-temporal pattern of accumulation rates on remote areas of the East Antarctic plateau.

The traverse was carried out within the framework of the International Polar Year (IPY), when a research team travelled through large parts of Dronning Maud Land, from the Norwegian

station Troll to South Pole in austral summer 2007/08 and back on a different route in 2008/09. The aim of the project is to improve understanding the mass balance of East Antarctica and its contribution to sea-level change, provide field data for calibration of model assessments as well as satellite-based estimates, and obtain information about climate signals and their changes within the last decades to about one millennium. Another important aspect of the Norwegian–US traverse project is to revisit sites measured during the South Pole Queen Maud Land Traverses (SPQMLT) in the 1960s and assess the legacy of these older data sets by updated records.

A vast amount of information was collected during the field seasons. It took many forms: radar data obtained

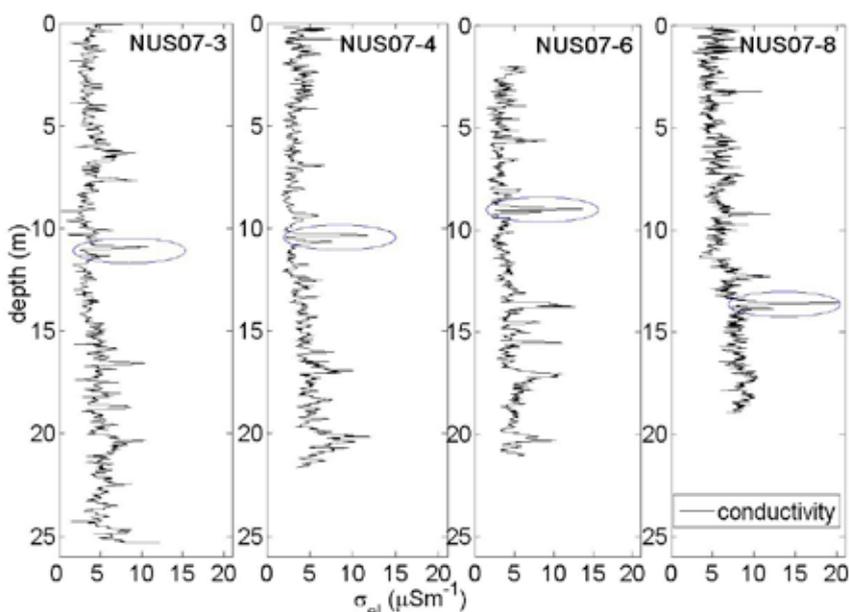




Map of the traverse route. Stein Tronstad (NPI)

using different frequencies, firn cores, snow samples, surface observations and temperature measurements, among others.

Four of the firn cores drilled in the first season were analysed in the cold laboratory at the Norwegian Polar Institute with a method called dielectric profiling (DEP) which measures electrical conductivity along the core. On the basis of these profiles, volcanic eruptions were detected and used for dating the firn cores. The well-known double peak of the eruption of Tambora in 1815 and an unknown volcano in 1809 were clearly visible in the conductivity records and served as an ab-



Electrical conductivity records of four firn cores from the season 2007/08. The blue ellipse marks the prominent double peak Tambora 1815/Unknown 1809 on which the dating is based. Graph: Helgard Anschütz (NPI)

solute time marker for the verification of dated strata. Thus, other prominent volcanic horizons such as Krakatau (1883) and Deception Island (1641) could be dated reliably. Using the established volcanic chronology and information about density, the mean accumulation rates between the volcanic horizons could be calculated.

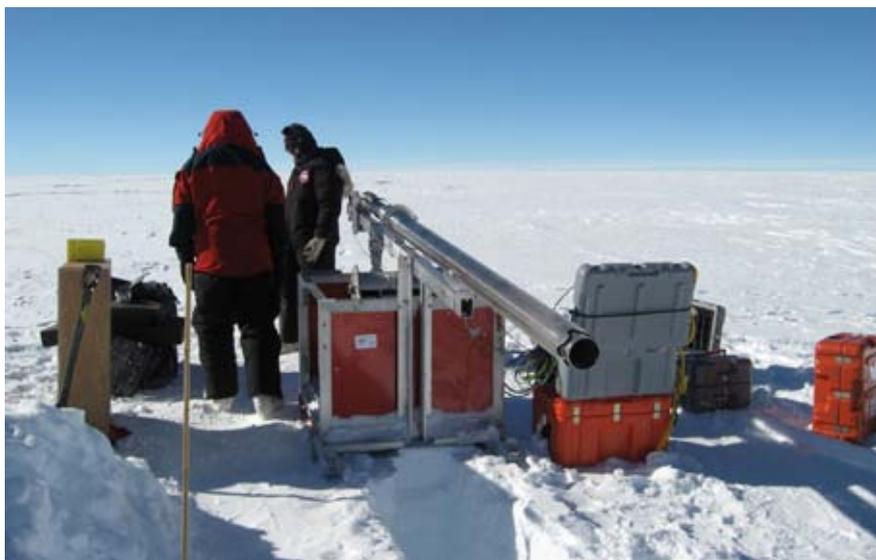
Our firn cores show accumulation rates in the range of 16-32 mm per year water equivalent averaged over the period 1815–2007. This is slightly less than expected from the SPQMLT data, suggesting that some parts of the East Antarctic plateau might have received even less precipitation than

previously assumed. Accumulation seems to decrease along the south-bound route, with the exception of the fourth firn core. Clearly, accumulation is inversely correlated with elevation in our data sets, fitting the expected spatial pattern well.

The variation in depth of radar layers we tracked suggests that our firn-core sites are representative of a larger area, but the possibility of comparing with other data from the wider area is limited due to different observation periods and large spatial distances between observation sites.

Concerning temporal variability, three firn cores show a decrease in accumulation of more than 20% for the time period 1815–2007 in relation to 1641–1815. Several other studies have reported an increase in accumulation during the Twentieth Century over parts of the East Antarctic plateau and the South Pole area. Even though we cannot sufficiently resolve a possible recent trend, our results suggest that accumulation increase might not be valid for the entire plateau and that the temporal changes could be more complicated than assumed. This has important implications for the estimation of the mass balance of the East Antarctic ice sheet.

Our results provide insight into the spatial and temporal variability of accumulation and contribute new data for this largely uncovered area.



Typical drilling site on the East Antarctic plateau. Photo: Helgard Anschütz (NPI)

Coastal erosion – a threat to the cultural heritage of Svalbard?

Anne-Catrine Flyen

anne.flyen@niku.no

Norwegian Institute for Cultural Heritage Research, Oslo

Svalbard was an international “common ground” until 1925, when it came under Norwegian jurisdiction. This Arctic archipelago has no signs of any indigenous population, but people from many countries have used Svalbard in a variety of ways for over 400 years, and Svalbard’s cultural sites are regarded as international heritage. It was a place for seasonal occupation and use, and most visitors based their livelihood on exploitation of natural resources, with hunting and mining as the principal activities. Permanent settlements were not established until early in the 20th century, when Norway and Russia started to carry out large-scale coal mining.

Cultural heritage sites are irreplaceable sources of historical information, providing insight into the social, religious and economic life of our ancestors. Historical remains in the Arctic tell a fascinating tale of the capability of humans to adapt to the cold climate and survive under tough conditions. In Svalbard, all structures

and artefacts related to human activity from before 1946 are considered worthy of preservation. In fact, ruins, grave markers and sites dating from prior to 1946 are automatically protected through the Svalbard Environmental Protection Act. There are cultural heritage sites and objects not just within settlements but all over the archipelago. Removing, moving or damaging any such items or sites is a punishable offence.

Among the historical relics in Svalbard are the remains of blubber-trying furnaces and small houses from the whaling industry in the 17th century, graves and graveyards from the same period, many small trapper huts from the 18th, 19th and 20th centuries. Svalbard’s coal mining history is reflected in mines, buildings, machinery and many other artefacts from the mining industry in the 18-1900s.

Many think of the permafrost as a perfect way to preserve historic artefacts: this is to some degree true, particularly for biological material. Yet Svalbard’s rugged landscape and hostile environment are tough on cultural remains. As most of the historical remains are situated very close to the shore, they are extremely vulnerable

to coastal erosion. Climate-related changes such as reduced permafrost, rising sea levels, less ice, and more winter storms with larger waves will further exacerbate this problem. Many graves and other remains have already disappeared into the sea and others are likely to follow in years to come.

The Svalbard archipelago houses more than two thousand historic sites, but many are inaccessible. There are no roads, there is no infrastructure; the weather conditions are rough and the winter is long and dark. How to cope with this? How can we find out where coastal erosion is a threat? What will the effect be, and when will it happen? Is it possible to prevent the gradual – or sometimes sudden – obliteration of fragile historical remains? Where should we start?

These are some of the questions the Governor of Svalbard wants answers to, in order to cope with the effects of climate change. The Norwegian Institute for Cultural Heritage Research (NIKU), in cooperation with the University Centre in Svalbard (UNIS), has been asked to try to find answers. More specifically, the Governor wants a method to identify sites that are threatened by coastal erosion.

In the winter of 2008 and the spring of 2009 scientists from NIKU and UNIS went through all existing maps and photographs from Svalbard. We also studied the archives at the District Governor of Svalbard and the Directorate for Cultural Heritage. During the summer and autumn of 2009 we visited several historic sites in Svalbard to investigate these problems in the field.

The trapper station Fredheim by Sassenfjorden. The fjord was an important hunting area for Pomors (Russian hunters) in the 1700s and 1800s, and for Norwegian trappers, including the legendary Hilmar Nøis. He spent 38 years in Spitsbergen, wintering all over Isfjorden and on the north coast, but eventually built his own station, naming it Villa Fredheim. The main building is from 1924. In the foreground is Danielbu, the first hut on the station, built by Hilmar’s uncle, Daniel Nøis, during the winter of 1911/12. Danielbu has several details characteristic of the building practices of the pioneer age of Norwegian winter hunting prior to World War I. The aerial photograph shows the river delta, which is growing and potentially protective.





Fredheim by Sassenfjorden. Coastal erosion brought the sea 11 metres closer to the main building between the first measurement in 1990 and September 2009. Danielbu, in the background, is the oldest building at the station. In 2001, this hut was moved several metres northeast from its original site when the encroaching shoreline came too close. All photos by the author.

We found that:

- there are scarcely any geological maps that show the surface layers of the coastal regions of Svalbard
- it is not possible to use existing maps or aerial photographs to identify active coastal erosion
- aerial photographs are currently not detailed enough to study the historic sites
- it is not possible to measure the exact position of cultural heritage sites from existing aerial photographs
- the cultural sites are heavily influenced by several kinds of geothreats, such as solifluction (widespread sediment transport downslope in periglacial environments), erosion from rivers and permafrost
- the coastal erosion at a cultural site may vary considerably within a relatively small area
- in some places erosion has moved the shoreline up to 11 metres closer to historic monuments between 1990 and 2009
- coastal erosion may be influenced by rivers forming deltas and building up a new shore: one river delta had grown 45 metres along the old shoreline between 1990 and 2009
- human activity may increase the problem

Both the archive studies and the field work showed that it is not possible to study historical sites under the influence of coastal erosion without getting out into the field. The data about the cultural sites are not detailed enough and the geological maps show bedrock, but not the crucial surface layers. To obtain a precise picture of the threat posed by coastal erosion it is necessary also to measure the effects of other geothreats. Since these vary from site to site – and even within a site – it is necessary to visit each individual historical site in order to evaluate the risk and effects of geothreats in short, medium and long term.

In addition, one must also weigh the historical value of the site and the technical condition of the ruins and artefacts themselves in order to prioritise the historical sites. This will tell us which historical sites are at risk of being washed out to sea, and which of them to prioritise. But it will not tell us how to save them from erosion.

Preventing coastal and fluvial erosion requires large interventions. This would disturb both the wilderness of Svalbard and the historical sites themselves. As many ruins are situated far from civilisation, with no infrastructure, it is difficult to reach them with technical equipment and machinery.

Thus the three most likely possibilities are to move valuable structures to a safer place nearby, to conduct archaeological excavations and save whatever can be saved, or simply to document the site and let nature take its course.

Centre for Ice, Climate and Ecosystems – ICE

What will happen when the Earth's climate changes? In polar regions, one of the most pressing research questions concerns the possible ramifications of global warming for the polar ice caps and the ecosystems that depend on them. Although there has been considerable progress, the interconnections between ice, climate and ecosystems remain poorly understood. To meet this need, the Norwegian Ministry for the Environment decided in late 2008 to grant funding

for a Centre for Ice, Climate and Ecosystems (ICE) under the auspices of the Norwegian Polar Institute. As soon as the resources became available the work of establishing the Centre began, and ICE was officially opened in March 2009.

ICE will further develop the Norwegian Polar Institute's position as a leading force in climate-related polar research, dealing with such topics as sea ice, snow, glaciers and effects of climate change on ice-associated eco-

systems in polar regions. Ecosystem studies will span species from lower trophic levels (sea algae and plankton) to the top of the food chain (seals and polar bears). The scope of ICE also includes international exchange of knowledge regarding the melting of high altitude glaciers, like those in the Andes and the Himalayas.

Much attention is given to energy and matter exchange between ocean, ice and atmosphere, as well as the thickness and distribution of the Arc-

tic sea ice. Another important subject for ICE is the ocean circulation in the Arctic and how this is linked to ice distribution and surface exchange processes.

A primary aim is to help improve the precision of climate models. ICE seeks to gain better understanding of climate processes through field studies and process modelling, which is later to be used in collaboration with national and international partners, such as the Norwegian Climate Centre, to improve the process depictions in the climate models.

The effects on ecosystems are approached by integrating ecosystem studies with studies of changes in the physical environment in icy waters. The focus is especially on species that depend on the ice, such as polar bears, some seal species, and ivory gulls. The aim is to develop an understanding of processes in the ecosystem which can be portrayed in climate models to approach quantitative calculations of the impacts climate change may have on the biological systems.

ICE's focus in the Antarctic is to understand the coupling between glacier dynamics and climate and how ice shelves are affected by changes in the climate (especially ocean temperature and circulation), as well as how changes in the ice shelves affect the inland ice.

The centre is headed by Dr. Nalân Koç, who previously led the Polar Climate Programme at the Norwegian Polar Institute. An advisory board with members from different Norwegian research institutions and environmental management agencies has been established. Presently three flagship projects exist within ICE: Fimbulisen (Antarctica), Sea Ice, and Ecosystems (both in the Arctic). ICE will, however, be flexible when it comes to meeting the environmental management needs of the Norwegian Government,



James Hansen, director of the NASA Goddard Institute for Space Studies, Erik Solheim, Minister of the Environment and International Development and NPI director Jan-Gunnar Winther opened ICE by sawing through an ice core from the Fram Strait east of Greenland. Photo: Jesper Hansen

and the focus of the flagships will change correspondingly with time.

During its first year, ICE was involved in a number of activities. In February eleven environmental ministers and experts were invited by Norway's Minister for the Environment to visit Troll Station in Antarctica, where they learned about climate research. In March Tromsø hosted an international meeting of the parties to the 1973 agreement on the conservation of polar bears, which concluded with a joint statement that "climate change has a negative impact on polar bears and their habitat, and is the most important long term threat facing polar bears".

The following month Minister for Foreign Affairs Jonas Gahr Støre and Nobel Peace Laureate Al Gore co-hosted a Melting Ice Conference in Tromsø under the auspices of ICE – resulting in a state-of-the-art report on melting ice around the globe, for presentation

at the UN climate summit meeting in Copenhagen in December 2009.

The High Mountain Glaciers and Global Change conference in June attracted participants from 21 countries to Tromsø; there was a fruitful exchange of existing knowledge, and knowledge gaps were identified.

In September, UN Secretary General Ban Ki-moon accompanied ICE researchers to the ice-edge and Svalbard, to learn about climate change. Standing on the Arctic sea ice, closely followed by media representatives, the Secretary General appealed to world citizens and leaders to take action to preserve the ice.

Alongside these activities the flagship projects were established, and more scientists were recruited by the Norwegian Polar Institute. In November, the ICE-Fimbulisen crew of oceanographers, glaciologists and technicians headed for Antarctica. The aim of the expedition to the immense ice shelf named Fimbulisen is to understand the interaction between the Antarctic ice sheet and the ocean. In this project, an Internet service for Norwegian schools was established as part of ICE School – a concept which will be further developed (see <http://fimbul.npolar.no>).



CENTRE FOR ICE, CLIMATE AND ECOSYSTEMS

Tromsø – early Arctic exploration and research

Tore O. Vorren

tore.vorren@uit.no

Department of Geology, University of Tromsø

The Tromsø region has an over thousand-year tradition in Arctic exploration and research. At the end of the ninth century a Viking nobleman named Ottar lived on the outskirts of what is now Tromsø. With his square-rigged Viking ship Ottar rounded Nordkapp (the North Cape Plateau) and sailed around the Kola Peninsula into the White Sea. We know of this voyage because Ottar later went on a trading trip across to England and met with King Alfred the Great. Alfred faithfully recorded Ottar's trips to the northern latitudes. So straightforward is the narrative, so clear and precise, that it is possible to trace the Viking's exact course.

Tromsø, the gateway to the Arctic

Tromsø was formally founded as a city in 1794. In the 1820s, skippers of

the merchant fleet took up sealing in the Arctic. If it was the early Dutch and British whalers who first unravelled the outlines of west Spitsbergen, the sealing captains from Tromsø and Hammerfest played an equally impressive role in the later phase of exploration of the Barents and Kara Seas. In this way Tromsø earned its nickname: "The gateway to the Arctic".

Inspired by the Spitsbergen expeditions of the Swedes O.M. Torell and A.E. Nordenskiöld, and encouraged by the Tromsø geologist, Karl Pettersen, the sealer captains made trips into unknown areas and collected valuable information.

Elling Carlsen

A nestor among the sealer captains was Elling Carlsen. In 1859 he observed Kong Karls land. Four years later he was the first person to circumnavigate the Svalbard archipelago.

In the year of 1871 Carlsen made a most remarkable discovery on the northern tip of Novaya Zemlja. There he found the remnants of Barents' last

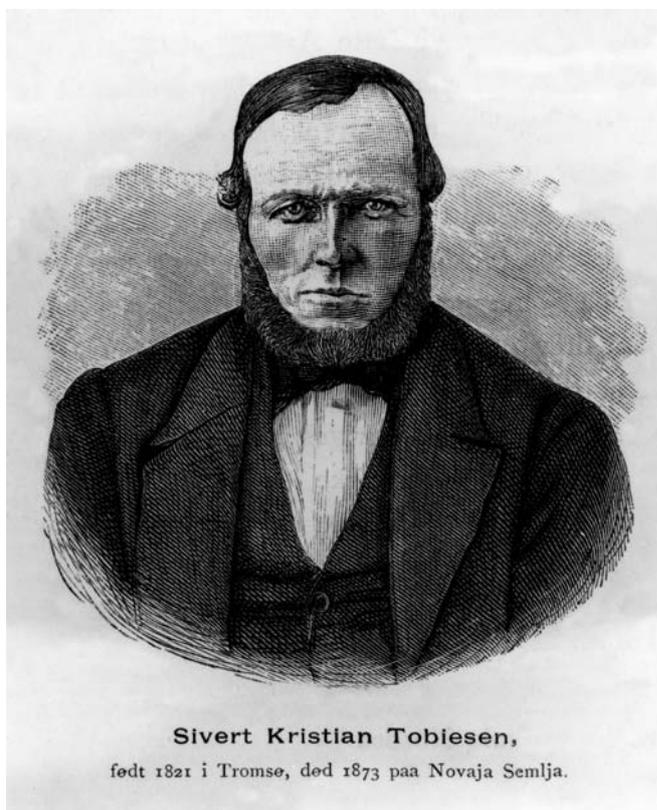
winter quarters. At the head of the bay stood Barents' house just as it had been left 275 years before. Protected from decay, guarded from devastation by prowling foxes and bears under a thick layer of ice that hermetically sealed the house, were the books, clothes, tools and utensils used by Barents' men during their long captivity. There was a clock, muskets, a flute, and the little shoes of the ship's boy who died there. Carlsen also found a letter that Barents had put in the chimney for safekeeping.

Elling Carlsen concluded his Arctic exploration on the Austrian Payer-Weyprecht expedition of 1872-1874, which discovered Franz Josef Land.

Sivert Tobiesen

Sivert Tobiesen is another remarkable sealing captain. Only thirteen years old, in 1834, he made his first trip as a cook onboard a vessel bringing a hunting crew to Bjørnøya (Bear Island).

In 1865 he went to Bjørnøya to overwinter. With the intention of making meteorological observations, he



Engravings of the Tromsø skippers Elling Carlsen and Sivert Kristian Tobiesen courtesy of Tromsø Museum



Amundsen's *Gjøa*. Originally a herring boat, the ship was purchased by Amundsen in 1900, refitted and her hull strengthened to withstand the ice conditions expected in the Northwest Passage. She can now be seen at the Norwegian Maritime Museum in Bygdøy, Oslo.

Photo: The Norwegian Polar Institute Photo Library

was equipped with a thermometer and a barometer. Unfortunately the barometer did not work, but he did manage to get the first, and for many years the only, continuous series of temperature measurements from this part of the Arctic. On this same overwintering he found the skeletons of some of the seven men set ashore by the vessel on which he had served as cook when he was a boy.

Seven years later, after having sailed between Spitsbergen and Novaja Zemlja further north than anybody had done before, Sivert Tobiesen's ship was caught by the ice and he was forced to overwinter on Novaja Zemlja. He and his son died there from scurvy the following spring. That same year spelled tragedy for many in Tromsø: twenty-one men perished and six good vessels were lost in the ice.

A new era

An event in Tromsø which encouraged exploration of the Arctic was the founding of Tromsø Museum in 1872. Hunters and sealers contributed

with material collected in the Arctic regions. Later expeditions followed in the hunters' footsteps and benefited from their experience. The hunters now played crucial roles as ice pilots, skippers and crew for national and foreign expeditions.

Fridtjof Nansen's great *Fram* expedition had three members from the Tromsø area: T.C. Jacobsen, P.L. Henriksen and B. Bentsen. Another expedition member, Hjalmar Johansen, later came to reside in Tromsø, though it was not his original home. After having been separated for a year or so, Nansen and Johansen and the ship came together in Tromsø on 21 August 1896. A great festivity took place in the house of Tromsø Arbeiderforening and outdoors at Alfheim where 2000 people were gathered. Amongst them was a young man, Helmer Hanssen, who was eager to participate in polar expeditions. Hanssen later accompanied Amundsen on his most spectacular quests.

Among the many well known small Norwegian vessels, *Gjøa* is perhaps the most famous – the first vessel

to sail through the Northwest Passage. *Gjøa* was built in Sunnhordaland and before she was purchased by Roald Amundsen she had been owned by the Tromsø sealer captain Hans Christian Johannessen, who sailed *Gjøa* in polar seas for many years. On one of these trips the Swedish polar scientist Axel Hamberg was on board. For some reason the relationship between Hamberg and Johannessen soured. After returning to Sweden, Hamberg wrote to one of his colleagues that he wanted to see Johannessen hung in the gallows on top of an actively erupting volcano. On Amundsen's expedition through the Northwest Passage, Tromsø natives Anton Lund and Helmer Hanssen served as second and third mate, respectively.

The first person to try to commercialise the coal on Spitsbergen was Søren Zakariassen. Like Carlsen and Tobiesen, he was a ship's captain and hailed from Tromsø. It is probably fair to say that the activity of Norwegian hunters on Svalbard was an important argument for giving Norway sovereignty over Svalbard after World War I.

VIPs on ice



In early September, as the Arctic sea ice was reaching its minimum extent, UN Secretary-General Ban Ki-moon went to Svalbard to learn more about climate change. Ban's first stop was Ny-Ålesund. There he visited the Korean Polar Research Institute's DASAN station and the Norwegian Polar Institute's Zeppelin station, where several research institutes led by the Norwegian Institute for Air Research do long-term monitoring of the atmosphere, including carbon dioxide, methane and other greenhouse gases. Then Ban and his host Erik Solheim, Norwegian Minister of the Environment and International Development, visited an international team of scientists engaged in a four-week research cruise on board the Norwegian Polar Institute research vessel *Lance*. Standing on a drifting ice floe, Ban and Solheim were briefed on the state of the Arctic sea ice and saw at first hand the methods scientists use to measure and assess ice properties and quantify key climate processes such as albedo. Speaking about the visit, Secretary-General Ban said, "I am here to see for myself the damage wrought on this fragile environment by climate change. Standing on the polar ice yesterday, I was overwhelmed by a sense not only of the power of nature but also of its vulnerability. It is now clearer to me what I as Secretary-General of the UN must do to take up the battle against climate change."

Safety first!

Seeking a livelihood in the far north is risky business. This is a vast, sparsely populated area, far from most of the modern-day infrastructure the rest of us essentially take for granted. In harsh Arctic conditions, a human being can be very small indeed. Conversely, human activities – shipping, fishing, and oil and gas operations – pose a threat to the vulnerable subarctic environment. Accidents happen, as illustrated in May this year, when the freezer vessel *Petrozavodsk* steamed full speed into the bird cliffs at the southern tip of Bjørnøya – cliffs densely populated by guillemots who were just starting their breeding season.

We need to know more about the challenges that face operations in Arctic and subarctic environments. To meet that need, the new research centre SESINOR was inaugurated in March 2009. SESINOR aims to mediate cooperation between research and commercial interests to promote innovative solutions for commerce in Northern Norway. Special focus will be on four areas: maritime activities, process and gas technology, safety and the environment, and automated processes. SESINOR is seated within the Department of Engineering and Safety at Tromsø University.

BARESS: a new research school

The Barents Remote Sensing School BARESS was established in February, with start-up funding from the Ministry of Foreign Affairs. Satellites are ideal for monitoring the vast unpopulated regions of the High North. There is great potential for using technological advances in remote sensing to improve monitoring of both natural processes (sea ice extent, glacial retreat, phytoplankton blooms) and human activities (shipping and oil spills). The decision to establish the school in Tromsø comes as no surprise to Tore Vorren, former Dean of the Faculty of Mathematics and Natural Science at Tromsø University. "[Remote sensing] is a research area that is expanding and is in great demand. In Tromsø we have everything from basic research to products." The school will be a part of the newly established Centre for Remote Technology, and will collaborate closely with other players in Tromsø, including Spacetec, Kongsberg Satellite Services, NORUT Northern Research Institute Tromsø, and the Norwegian Polar Institute. The school will initially recruit three to five PhD students but is expected to grow over time.



Top: UN Secretary-General Ban Ki-moon and Norwegian Minister Erik Solheim on Arctic sea ice. Photo: Sebastian Gerland (NPI)
Bottom: *Petrozavodsk* aground at the southern tip of Bjørnøya (Bear Island) among thousands of breeding guillemots. Photo: Harald Steen (NPI)

Doctorates in polar studies at the University of Tromsø

Dr. Philos

Arne Johannes Eide

arne.eide@uit.no

Bioeconomic Perspective on the Norwegian Barents Sea Cod Fishery (2008)

PhD

Erik Eik Anda

erik.anda@uit.no

The Murmansk County Birth Registry (MCBR). The implementation and applicability of a population-based birth registry in the Russian Arctic

Bård-Jørgen Bårdsen

bjb@nina.no

Risk sensitive reproductive strategies - The effect of environmental unpredictability

Irene Vanja Dahl

irene.dahl@uit.no

Norsk fiskerijurisdiksjon overfor utenlandske fiskerfartøyer

John Andre Henden

john-andre.henden@uit.no

Changing circumstances: Implications for trophic dynamics and species conservation in the Fennoscandian Tundra

Steinar Hustoft

steinarhustoft@hotmail.com

Spatial and temporal analysis of fluid venting systems on the Norwegian-Svalbard margin

Hallvard Jensen

Ecological factors affecting piscivory of brown trout (*Salmo trutta* L.) in northern lakes

Aurèlie Paulette Andrée Justwan

Holocene climate variability of the East Greenland Current and Irminger Current system

Virve Tuulia Ravolainen

virve.ravolainen@uit.no

Tundra plant diversity as influenced by biotic interactions

Svein Vigeland Rottem

svi000@post.uit.no

What is Norway Defending? The Norwegian Defence's Encounter With a New Reality

Kari-Lise Rørvik

kari-lise.rorvik@uit.no

The NE Nordic Seas during the Last Glacial Maximum and Holocene; a multi-proxy perspective

Kjetil Sagerup

kjetil.sagerup@uit.no

POP-cocktails: Hangover threats for seabirds? The response of three seabird species to exposure to persistent organic pollutants in the Barents Sea. (Joint supervision with the Norwegian Polar Institute)

Sigmund Vegard Sperstad

sigmund.sperstad@uit.no

Characterisation of antimicrobial peptides from the spider crab, *Hyas araneus* (Decapoda, Crustacea)

Kirsti Stuvøy

kirsti.stuvoy@uit.no

Security Under Construction. A Bourdieusian Approach to Non-state Crisis Centres in Northwest Russia

Jörg Otto Welcker

jorg@npolar.no

Behavioral and energetic response of Arctic-breeding seabirds to environmental variability. (Joint supervision with the Norwegian Polar Institute)

Jon-Ivar Westgaard

jon-ivar.westgaard@imr.no

Characteristics of the population structure in species of fish displaying different dispersal capacities. (Joint supervision with the Institute of Marine Research)

Anja Celine Winger

anja.winger@uit.no

Arctic charr (*Salvelinus alpinus* (L.)), an adequate host to *Gyrodactylus salaris* (Monogenea)

Sigurd Aanestad

Essays on the Exploitation of Natural Resources: Optimal Control Theory applied to Multi-species fisheries and Fossil fuel Extraction

Lena Aarekol

lena.aarekol@uit.no

Kvenske minnesteder 1970-2001. Materialitet og minne

Kristian Åtland

kristian.atland@uit.no

The European Arctic in Soviet and Russian Security Policy, 1987-2007. A Collection of Articles drawing on "Copenhagen School" Theory

Doctorates in polar studies at other Universities

PhD

Mats Björkman

mats.bjorkman@npolar.no

Nitrogen dynamics in the winter snow pack.

University of Oslo. (Joint supervision with the Norwegian Polar Institute)

Rafael Kühnel

Rafael.kuhnel@npolar.no

Atmospheric nitrogen in the polar region University of Oslo. (Joint supervision with the Norwegian Polar Institute)

Heli Routti

Heli.Routti@npolar.no

Biotransformation and endocrine disruptive effects of contaminants in ringed seals – implications for monitoring and risk assessment

University of Turku. (Joint supervision with the Norwegian Polar Institute)

RETURN ADDRESS:

Department of Communications
University of Tromsø
N-9037 Tromsø, Norway



USEFUL CONTACTS IN AND AROUND TROMSØ

INSTITUTIONS AT THE POLAR ENVIRONMENTAL CENTRE

N-9296 Tromsø
Ph: +47 7775 0000
www.polarenvironment.no

Akvaplan-niva AS
Ph: +47 7775 0300 Fax: +47 7775 0301
www.akvaplan.niva.no

Arktika Conference Centre
Ph: +47 7775 0250 Fax: +47 7775 0251
www.arktika.no

Geological Survey of Norway
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www.ngu.no

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www.nilu.no

Norwegian Institute for Nature Research
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Norwegian Mapping Authority Tromsø
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Norwegian Polar Institute
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npweb.npolar.no

Norwegian Coastal Administration
Ph: +47 7775 0480 Fax: +47 7775 0481
www.kystverket.no

Norwegian Radiation Protection Authority
Ph: +47 7775 0170 Fax: +47 7775 0171
www.nrpa.no

Polarmiljøsesteret AS
Ph: +47 7775 0200 Fax: +47 7775 0201
www.polarenvironment.no

UNILAB Analyse Ltd.
Ph: +47 7775 0350 Fax: +47 7775 0301
www.unilab.no

Norwegian Nature Inspectorate
Ph: +47 7775 0190 Fax: +47 7775 0191
www.dirnat.no

NORUT NORTHERN RESEARCH INSTITUTE

www.norut.no
NORUT Tromsø
P.O.B. 6434 Forskningsparken, N-9294 Tromsø
Ph: +47 7762 9400 Fax: +47 7762 9401
www.itek.norut.no

NORUT Alta
P.O.B. 1463, N-9506 Alta
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P.O.B. 6413 Forskningsparken, N-9294 Tromsø
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www.norinnova.no

NOFIMA
P.O.B. 6122, N-9291 Tromsø
Ph: +47 7762 9000 Fax: +47 7762 9100
www.nofima.no

FACULTIES, DEPARTMENTS AND CENTRES AT THE UNIVERSITY OF TROMSØ

N-9037 Tromsø
Ph: +47 7764 4000
uit.no

Centre for Women's and Gender Research
Ph: +47 7764 5240 Fax: +47 7764 6420
E-mail: kvinnforsk@skk.uit.no

Centre for Sámi Studies
Ph: 47 7764 5535 Fax: +47 7764 5510
E-mail: postmottak@sami.uit.no

Faculty of Biosciences, Fisheries and Economics

Ph: +47 7764 6000 Fax: +47 7764 6020

E-mail: postmottak@bfe.uit.no

Departments:

- Department of Arctic and Marine Biology
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E-mail: postmottak@kunstfak.uit.no

Departments:

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Faculty of Health Sciences

Ph: +47 7764 4601 Fax: +47 7764 5300

E-mail: postmottak@helsefak.uit.no

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Faculty of Law

Ph: +47 7764 4197 Fax: +47 7764 4775

E-mail: postmottak@jus.uit.no

Faculty of Science and Technology

Ph: +47 7764 4001 Fax: +47 7764 4765

E-mail: postmottak@matnat.uit.no

Departments:

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Ph: +47 7764 5000 Fax: +47 7764 5520

E-mail: museumspost@uit.no

The University Library of Tromsø

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E-mail: ubweb@ub.uit.no

OTHER INSTITUTIONS

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P.O.B. 54, N-8483 Andenes
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Ph: +47 7760 0550 Fax: +47 7760 0551
www.eiscat.no

Institute of Marine Research Tromsø
P.O.B. 6404, N-9294 Tromsø
Ph: +47 5523 8500 Fax: +47 7760 9701
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Ph: +47 7775 0180 Fax: +47 7775 0181
www.nammco.no

National Archives of Norway,
Regional State Archives of Tromsø
N-9293 Tromsø
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Norwegian Centre for Telemedicine,
University Hospital of North Norway
P.O.B. 35, N-9038 Tromsø
Ph: +47 7775 4000 Fax: +47 7775 4098
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Norwegian Meteorological Institute,
Division for Northern Norway
P.O.B. 6314, N-9293 Tromsø
Ph: +47 7762 1300 Fax: +47 7762 1301
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Norwegian School of Veterinary Science
Dept. of Arctic Veterinary Medicine
Stakkevollveien 23, N-9010 Tromsø
Ph: +47 7766 5400 Fax: +47 7769 4911
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Polar Museum
P.O.B. 900, N-9259 Tromsø
Ph: +47 7760 6630 Fax: +47 7761 1720
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Ph: +47 7775 0100 Fax: +47 7775 0101
www.polaria.no

Bioforsk, Norwegian Institute for Agricultural and Environmental Research
Svanhovd, N-9925 Svanvik
Ph: +47 4641 3600 Fax: +47 7899 5600
www.svanhovd.no

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ISSN 1891-5019 (print version)

ISSN 1891-5027 (online version)