2006

POLAR RESEARCH IN TROMSØ

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POLARMILJØSENTERET

NORSK POLARINSTITUTT

INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

UNIVERSITY OF TROMSØ

A change of heart on climate change

It's funny how trends sweep through society. For years, scientists have been pointing to the potential danger of increased emission of greenhouse gases. These warnings were often met with scepticism, but now, one by one, the critics have come around. Suddenly everyone is talking about climate change. In homes and workplaces, schools and cafés, people are discussing global warming as a reality – and a threat.

For Tromsø residents, this hits particularly close to home, as climate change is predicted to be both early and dramatic in Arctic regions. It is therefore fitting that the United Nations Environment Programme has selected Tromsø to host the international World Environment Day in June 2007 under the slogan "Melting ice – a hot topic?" Read more at www.wed.npolar.no or www.unep.org/wed/2007/english.

Two of the past year's most well-publicized contributions to the global warming debate came from Al Gore, former vice president of the United States, and Sir Nicholas Stern, former chief economist of the World Bank. Gore's movie *An Inconvenient Truth* premiered in Norway in October. *The Stern Review on the Economics of Climate Change* was released in November. Though their approaches are different, both presentations conclude that the threat of global warming is real. They also agree on another crucial point: we must not give in to despair. Something can and should be done. The Stern Review suggests actions available mainly to policy-makers and corporations, but *An Inconvenient Truth* lists things ordinary people can do to counteract global warming. See the list at www.climatecrisis.net/takeaction.

What is the research community doing?

We know the Earth's climate is strongly influenced by processes that occur at high latitudes. Conversely, it is also clear that polar regions are affected by climate. Perturbations in this system will undoubtedly have far-reaching consequences. Yet many of the causal links remain obscure. How do clouds and soot affect the amount of solar energy that reaches the Earth's surface and is trapped here? How will ice caps be influenced by global warming? How will changes in sea ice affect water temperature and salinity? What effects might we see on ocean currents, on sea level, or on the ocean's ability to take up carbon dioxide? During the International Polar Year 2007-2008 scientists from around the world will join together and try to fill in some of the knowledge gaps.

True to its tradition as a polar nation, Norway has ambitious plans to study how polar climate works, how it affects environments and the organisms that live there. Nearly thirty projects will be carried out with funding from the Norwegian Research Council and other agencies. Research institutes based in Tromsø will be involved in many of the projects.

Although little of the work described in this year's issue of Polar Research in Tromsø deals directly with climate change, the articles highlight the vulnerability of organisms at high latitudes – and remind us we are stewards of the precious natural resources at our doorstep.

Tromsø, December 2006
The Editors

Polar Research in Tromsø

Polar Research in Tromsø is published once a year by the Roald Amundsen Centre for Arctic Research at the University of Tromsø, the Norwegian Polar Institute, the Tromsø branch of the Institute of Marine Research and the Polar Environmental Centre, 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.

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Population biology of ringed seals in Svalbard, Norway

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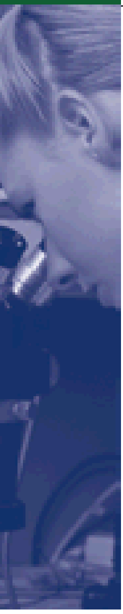
Ringed seal on ice. Photo: Kit M. Kovacs and Christian Lydersen

Ringed seals (*Phoca hispida*) play a key ecological role in the Arctic ecosystem. This small, abundant, seal is found in virtually all seas and oceans encircling the North Pole. They are the main prey species of polar bears and an important resource for indigenous people in coastal areas throughout the Arctic. Despite the importance of ringed seals for both ecology and human subsistence, knowledge of stock identities, trends in the size and structure of their populations and "health" is generally sparse. The reasons for this are known well by Arctic scientists that have attempted to work with this species, which lives in a logistically challenging environment and spends most of the year broadly dispersed in northern ice-filled waters. Even during the part of the year when the seals come into coastal areas to reproduce, they spend a lot of time in the water beneath the ice, and when they are on the ice, they spend much of the time in small caves built in snow drifts – so they are in fact inaccessible most of the time. Despite the difficulties ringed seals present to researchers, knowledge of trends in their abundance and possible changes in their general ecology or population biology, over a significant time scale, is essential in order to understand the dynamics of the Arctic ecosystem.

The Norwegian Polar Institute's current ringed seal programme (2002-2007) was designed to explore important aspects of ringed seal population biology and ecology and provide the first comparative data in a time-track for this population. Eight projects were developed to expand our general knowledge of ringed seal population ecology in Svalbard; several of these projects were specifically selected because they would contribute essential information to local and national management plans as well as international ringed seal monitoring networks. The programme involved one PhD and three MSc students and included studies of: 1) spring and early summer haul-out behaviour; 2) determination of density and abundance of ringed seals in selected fjords; 3) diet of ringed seals in Svalbard; 4) a comparative study of population parameters determined in 1981-82 and the present to investigate potential changes in vital rates or the age and sex structure of the population; 5) an evaluation of the population's condition and "health" status (blubber reserves, concentrations of various metabolites in blood, and parasite infestations); 6) space use during the spring season; 7) assessment of contaminant exposure and effects on steroid homeostasis; and 8) local population sub-structure (genetics).

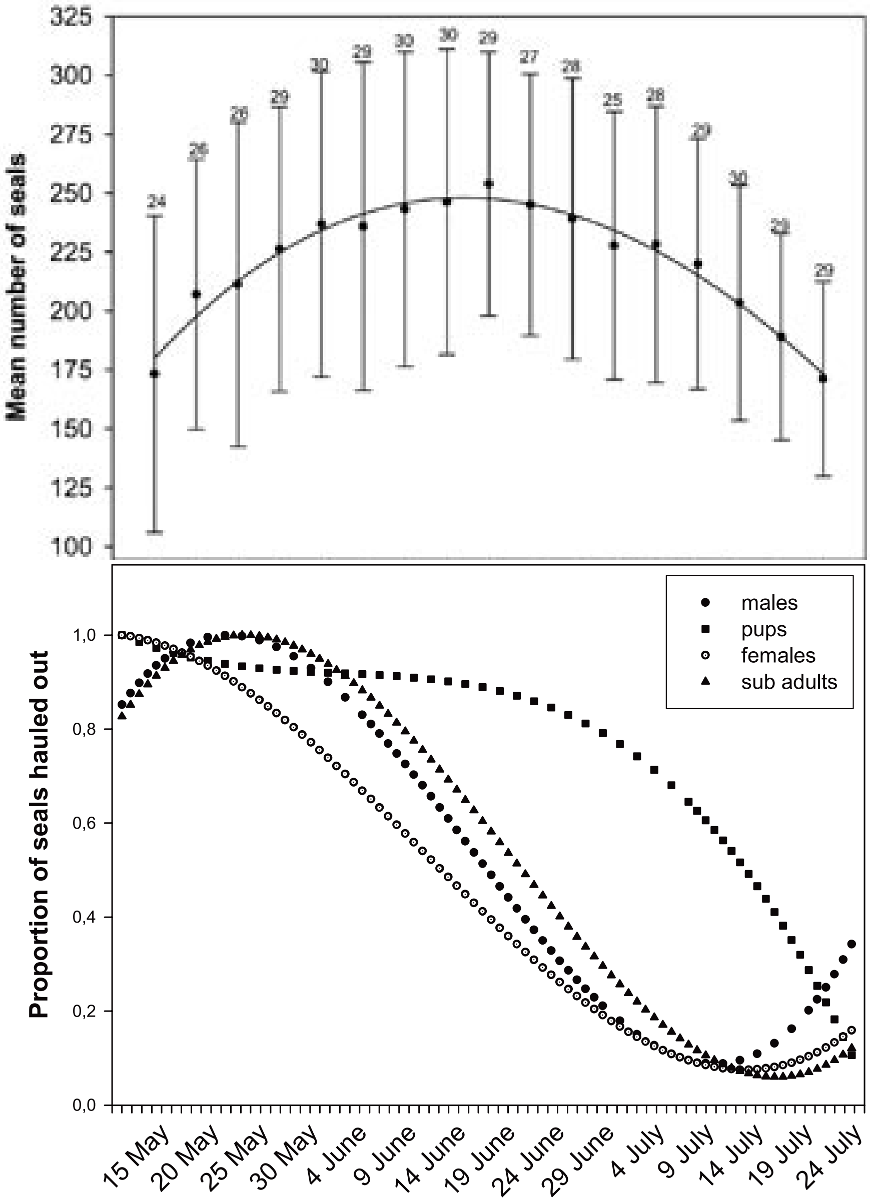
Our studies completed to date have revealed that time of day, temperature and wind speed all affected the number of seals hauled out during the moult. A surprising finding from the behavioural work was that the seasonal peak of haul-out for 24 VHF-tagged seals preceded the peak in seasonal counts in Kongsfjorden by three weeks (see graph). This strongly suggests a significant out- and in-flux of seals from and to the area. This mobility phenomenon is not accounted for when ringed seal abundance estimates are conducted, but these movements occur at a magnitude that certainly requires further research attention. Thus, our abundance estimate for 18 of Spitsbergen's fjords (7,585 (95% CI 6,332 – 9,085) ringed seals) must be considered an "index", or at least a minimum estimate for the area, because it does not account for individuals leaving the coastal areas prior to the population's peak haul-out period.

The diet of ringed seals in Svalbard is dominated by a single species, the polar cod, similar to findings from the early 1980's, but local variation does exist, apparently influenced by the relative amount of Atlantic water vs. Arctic water in the various fjords. The ringed seal population in Svalbard



was found to be in good health, with low toxic burdens, normal parasite loads, and no "surprises" with regard to veterinary-health measurements of blood values. However, some things have changed over the last 20 years in this population. The average age at which animals reach adulthood has declined, which in all probability reflects a reduction in ringed seal density. This may well be natural – our polar bear population has increased significantly since it became protected in 1973 – but it is certainly one of the factors that will be on our list to monitor into the future.

Ringed seal at haul-out hole covered by net. Photo: Kit M. Kovacs and Christian Lydersen



Polar cod: a key species for environmental risk assessment and monitoring of oil and gas activities in the Barents Sea

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Reliable environmental monitoring tools adapted for the Arctic environment are needed to identify and document potential impacts associated with the expanding activity of oil and gas industries in the Barents Sea. As a consequence of the "zero discharge" policy for the Barents Sea, the main environmental issue of concern is accidental discharges that occur during production or transport of petroleum products.

The ice-covered waters of the northern and eastern Barents Sea contain a flora and fauna with specialized adaptations that enable them to survive in Arctic environmental conditions, but also render them sensitive and perhaps vulnerable. For many Arctic species, the life cycles, adaptations and physiological mechanisms are poorly understood, and knowledge concerning the species' sensitivity to contamination and disturbance

The live-fish-box employed for catching live polar cod in Kongsfjorden at 300 m depth. Photo: Lionel Camus.

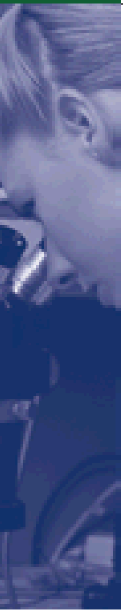
is also fragmentary. Therefore, there is a need for data to support environmental risk and impact assessments and to validate monitoring tools on a sentinel Arctic species.

The polar cod (*Boreogadus saida*) in the Barents Sea is the only fish whose life-cycle is closely associated with the ice-edge ecosystem. The polar cod stock was estimated to be as large as 2 million tons in the Barents Sea in 2001. Given its importance as forage species in the Arctic marine food web, the polar cod is considered an ecological key species, transferring energy from lower trophic levels to top predators such as birds, fish, seals and whales. Because of its high abundance and broad distribution in icy waters, this fish is potentially of great importance to monitor the effect of pollution in the Arctic marine food web and the sea ice environment.

Based on the importance of polar cod in the Arctic marine ecosystem and its potential for monitoring effects of pollution, ConocoPhillips funded a three-year research project (2006-2009), including support for a PhD student, to carry out some fundamental biological and ecotoxicological studies to identify biological responses of polar cod to oil exposure. The project is led by Akvaplan-niva in close association with the ARCTOS partners: the Norwegian Polar Institute and the University of Tromsø. The Norwegian Institute for Water Research and IRIS-Akvamiljø will also contribute significantly to the project. Foreign partners include the National Oceanic and Atmospheric Administration (Auke Bay, Juneau, Alaska), the Institute of Biology at the Karelian Research Center (Russian Academy of Science), the Murmansk Marine Biological Institute (Russia), and the research group of GEMA (UMR 5805 EPOC, CNRS and Bordeaux 1 University) located in the Marine Biological Station of Arcachon. Some information is available on the website: http://polarcod.akvaplan.com/

The project will evaluate a suite of biomarkers validated with Atlantic cod (*Gadus morhua*) for biomonitoring of oil and gas activities in the North Sea. Short-term (one week) and long-term (minimum of one month) exposure to crude oil will be considered. These techniques would provide information on the health status of the fish following acute and chronic exposure to polluted conditions. The methods that render the best information can subsequently be used to monitor the impact of an oil spill on marine fauna. These include well established methods, such as measurement of bile metabolites, EROD (ethoxyresorufin O-deethylation) activity, histopathology, DNA adducts, DNA microarray, vitellogenin and we will optimize a method for use on frozen samples, the comet assay. Uptake, depuration rates and bioaccumulation factors will also be measured. We will look at the expression of genes, quantify proteins and measure enzyme activities (cytochrome P450). Furthermore, we will investigate the antifreeze properties and the metabolic functions of the polar cod in relation to the seasonal variation. The differences in the biological responses to crude oil of adult polar cod and Atlantic cod will be investigated based on knowledge of

The polar cod (*Boreogadus saida*) lying between ice sheets. Photo: Bjørn Gulliksen



the physiological differences between Arctic and temperate latitude species (e.g. Arctic species have antifreeze molecules in their blood, and have lower kidney function and higher lipid content than species from temperate areas). These differences can lead to Arctic species being exposed to toxic molecules longer than corresponding temperate species. This highlights both the possible sensitivity of Arctic species to oil contamination and the potential difficulty of extrapolating data obtained with temperate organisms to an Arctic context.

The studies began this year. Polar cod have been obtained by trawling in Kongsfjorden using a live-fish-box (fish lift) in April and September 2006. The fish were subsequently transferred to holding facilities at the Arctic Marine Laboratory in Ny-Ålesund, Svalbard, where they are maintained in good condition for acclimation prior to experiments. This approach reduces the stress to the fish from handling during the exposure experiments. The first exposure study was done in the beginning of November 2006.

At the end of the project, we will provide an assessment of the long-term impact of oil on the polar cod and of the species' sensitivity. A toolbox for biomonitoring purposes will also be established. These data will help support the development of appropriate risk management systems applicable in cold water environments, especially the Barents Sea.

Habitat and food choice of Arctic charr in Linnévatn on Spitsbergen, Svalbard: the first year-round investigation in a High Arctic lake

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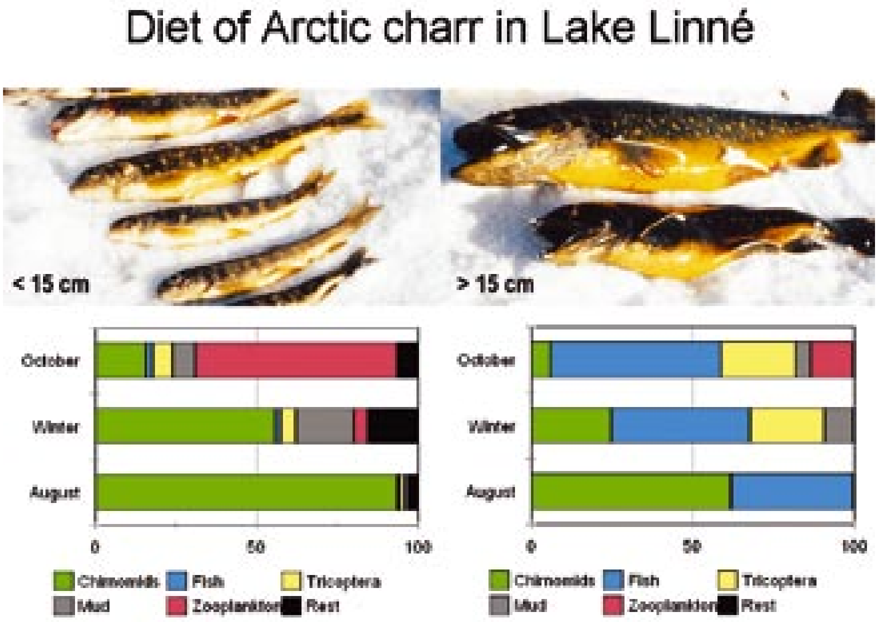


Diet of Arctic charr in Lake Linné, Svalbard, based on monthly sampling throughout a whole year. Winter period is from November to July, i.e., when there is ice cover.

The Arctic charr has a Holarctic distribution and demonstrates tremendous ecological plasticity and adaptation to harsh environments. It is the only freshwater fish species in most freshwater lakes in High Arctic regions, for instance in Svalbard. Most Svalbard lakes are ice-covered for at least 9-11 months a year with maximum water temperatures of 3-6 °C in summer/autumn. Despite the seasonal dominance of ice cover in these areas, very little is known about the ecology of species such as Arctic charr that live under the ice. To our knowledge, this study is the first year-round investigation in a High Arctic lake.

Winter water temperatures are not very different in dimictic (temperate, sub-Arctic) and cold monomictic (Arctic) lakes because inverse temperature profiles develop under the ice in all cases. The main differences are the extended period of polar darkness and the much longer ice season at high latitudes, and consequently significantly lower summer water temperatures. In the sub-Arctic lake Takvatn, in northern Norway, the ice-free period usually lasts for 6 months, with maximum water temperatures of about 15 °C. This is in strong contrast to Linnévatn, Svalbard (this study), with an ice-free season of 2-3 months and no record of temperatures above 4 °C. Arctic lakes also tend to have thicker and clearer ice and less snow. Linnévatn (4.6 km^2) it is the second largest lake in Svalbard. The ice cover is usually absent from late July to mid August and the ice thickness gradually builds up to a maximum of 1.7-2 m in May/June. The water temperature varies little from late October to early July, being around 1 °C, while the open water temperatures may rise to

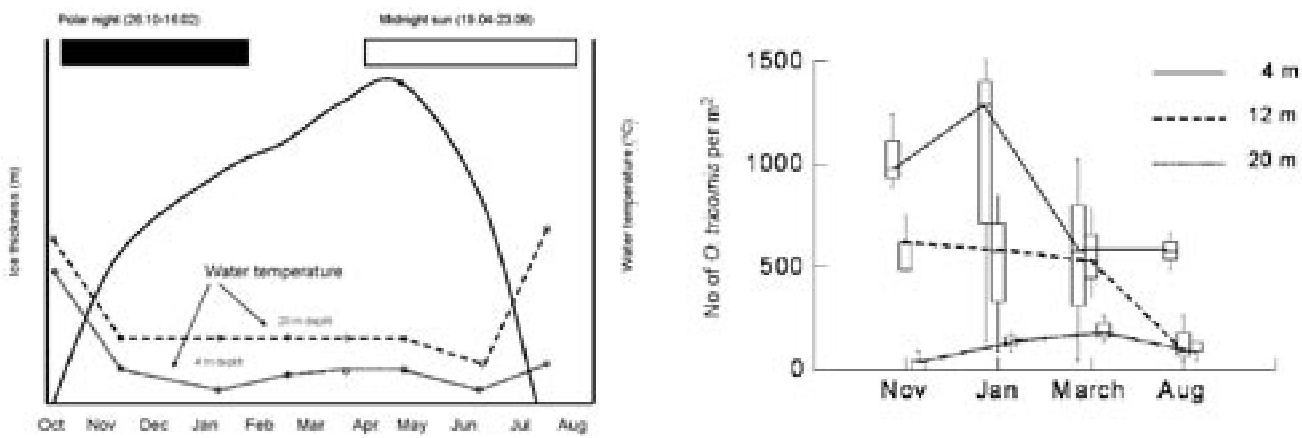
a maximum of 3.6 °C in early August. The sun is below the horizon (polar night) at this latitude from 26 October to 16 February, and the midnight sun lasts from 19 April to 23 August.

We wanted to test if the charr fed continuously during the winter in the High Arctic Linnévatn, where winter is both darker (four months of polar darkness) and longer (nine to ten months of ice) than in sub-Arctic lakes. The food resources of High Arctic lakes are much less diverse and dense, but the prey availability should have a seasonal pattern similar to that of sub-Arctic lakes. Therefore, we expected charr in Linnévatn to congregate in the upper littoral zone during the winter and to feed readily on benthos (bottom-dwellers). Larger resident charr are presumably cannibalistic during the ice-free period; thus we expected that larger charr in Linnévatn would also congregate in the littoral zone but show a tendency to feed on small charr.

Fish were sampled in eight periods (separated by 5-7 weeks) throughout the whole year by use of gillnets set from 4 to 20 m depth. One sample was taken before the lake froze (October), and one sample was taken after the ice broke up (August). Food items were identified and their relative contribution to stomach fullness estimated. Percentage occurrences, specific abundance of prey species and dietary overlap were calculated. Bottom samples were collected from each depth on each date with an Ekman grab.

The following conclusions can be drawn on habitat and food choice of Arctic charr from this first year-round study in a High Arctic lake. As predicted, we found that the charr fed continuously during the nine-month Arctic winter. The food intake was low during the darkest period and increased towards the end of the ice period. The diet of small charr (<15 cm) was strongly characterized by larvae of the chironomid *Oliveridia tricornis* during the winter. Larger charr (>15 cm) were mainly cannibals. There were indications that the fish cropped down chironomid density in shallow water during the winter. Charr density (CPUE) varied more with season and depth than predicted. Many fish were caught in deeper water later in the winter. Pupae of chironomids (*O. tricornis*) dominated the food of small charr in the summer while the copepod *Cyclops abyssorum* dominated in late autumn. For small charr (which dominated the population), there was a seasonal dietary shift from chironomid larvae in the winter, to chironomid pupae during the summer and zooplankton in late autumn, but this shift relied on just two species of invertebrate prey.

For more information, see Svenning, M-A., Klemetsen, A. & Olsen, T. 2006. Habitat and food choice of Arctic charr in Linnévatn on Spitsbergen, Svalbard: the First year-round investigation in a High Arctic lake. *Ecology of freshwater fish* (in press, 2006).



Left graph: Seasonal variation in ice thickness (solid line), and water temperatures at 4 and 20 m depths (broken lines) in Linnévatn. The periods of polar night and midnight sun are also indicated. Right graph: Density variation with season and depth of *Oliveridia tricornis* larvae (Chironomidae) from Linnévatn. The box plots show medians, maximum and minimum values and 95% confidence limits.

Ocean dynamics in the Nordic Seas and Arctic Ocean

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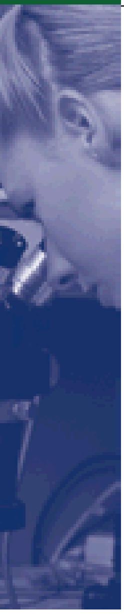
Oceanographers call the ocean region between Norway and Greenland the Nordic Seas. These seas and the Arctic Ocean (Figure 1) are separated by the Fram Strait, between Svalbard and Greenland and by the Barents Sea. One of the more striking features of the large-scale ocean circulation within the Nordic Seas and Arctic Ocean is the way the currents trace out the shape of the underlying ocean basins. Even the surface flow follows the topographic features that form subbasins, ridges and plateaus hundreds or even thousands of meters below. This phenomenon, referred to as topographic steering, is well known, and was observed by Helland Hansen and



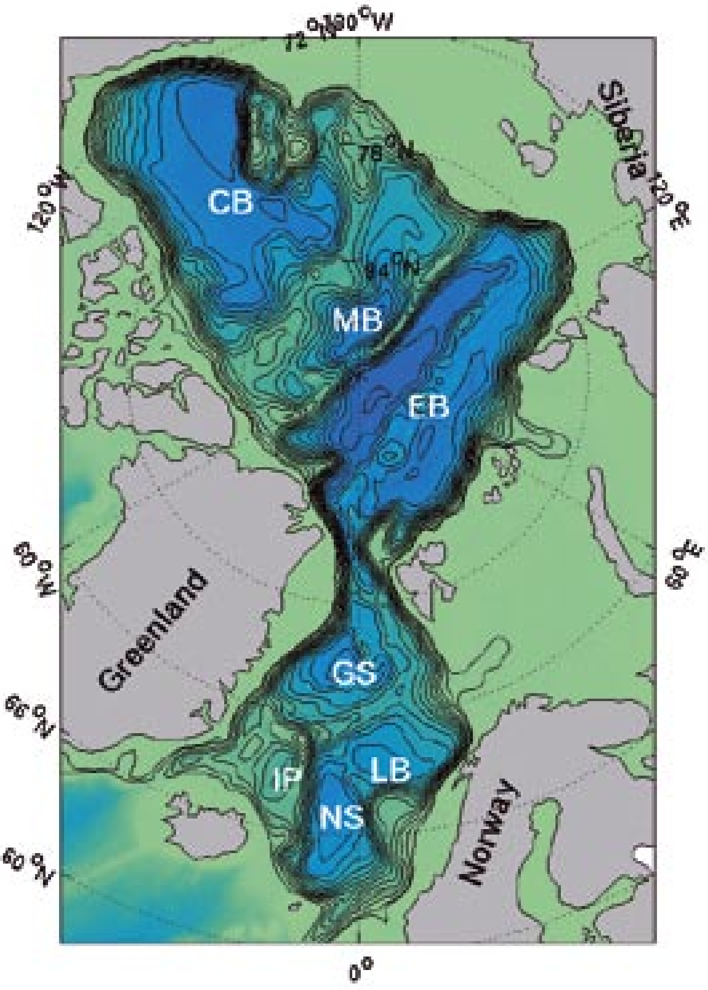


Figure 1. Map of the Nordic Seas and Arctic Ocean. Black lines are depth contours. Note the many closed basins in the region. The deepest areas (down to about 4000 m) are coloured blue while the shallowest areas are coloured green. The major basins are marked with their initials. CB – Canada Basin, MB -- Makarov Basin, EB -- Eurasian Basin, GS -- Greenland Sea, LB -- Lofoten Basin, NS -- Norwegian Sea, IP -- Iceland Plateau.

Nansen nearly a century ago.

For the ocean circulation to be steered by the bottom topography, the ocean currents must extend from surface to bottom. Observations show that this is indeed the case. This fact has been used to construct a simple, yet accurate, model of the large-scale ocean circulation in the Nordic Seas and Arctic Ocean. The basic physics of the model is that the wind forcing at the surface is balanced by friction at the bottom. This balance is not local. Rather, the near-bottom velocity at a certain location is given by the averaged effect of winds and friction acting on the water masses within areas enclosed by the depth contour going through the location. In some places (Greenland Sea, Lofoten Basin, Norwegian Sea) this area is relatively small, but in others, the current is influenced by winds and friction in all of the Arctic basin and the Nordic Sea. Using temperature and salinity observations together with wind stress data, all averaged over the last 50 years, gives the bottom velocity field shown in Figure 2.

From the bottom velocities we may calculate the surface velocities from observations of temperature and salinity, using a standard oceanographic method. Figure 3 compares calculated surface velocities and velocities estimated by surface drifters. As can be seen, the agreement is quite good. In fact, even state-of-the-art numerical models simulating the ocean circulation in this region do not show as good an agreement with observations.

More importantly, the simplified model gives us important hints about how these high-latitude oceans transport and distribute the warm Atlantic waters that make our climate as moderate as it is. The large-scale currents mainly follow topographic features like the continental slope and have difficulties in entering the many closed basins. Yet observations show that the heat loss from ocean to atmosphere is significant over some of these basins, and lost heat must be replaced by warm water. So how does warm water enter the basins? The answer is that it is not the large-scale currents that do the job, but rather smaller-scale fluctuations on the mean flow, so-called eddies.

Eddies in the oceans are the equivalent of weather systems in the atmosphere. It has been known for more than half a century that eddies in the atmosphere are the mechanism by which heat is transported poleward beyond the tropics. It was thought, however, that large scale currents did the job in most parts of the ocean. But in the Nordic Seas and Arctic Ocean the large-scale currents clearly are not sufficient, and it seems the eddies are doing the job. In fact, it is not just heat which is transported around by eddies but just about anything found in the water, including the chemical and biological substances that provide the basis for the marine ecosystem.

Understanding the dynamics of ocean eddies will help us refine our models of the oceans at high latitudes. Researchers at the Norwegian Polar

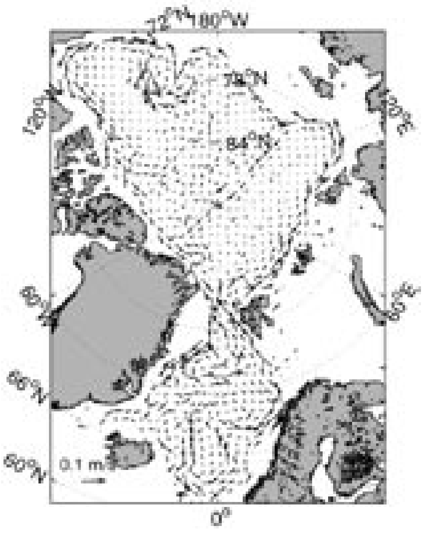


Figure 2. Bottom velocities from the simplified model. The velocities follow contours of constant depth.

Institute are now trying to model eddies and eddy transport mechanisms, in cooperation with other researchers from both Norwegian and foreign institutions.

For more information, see Nøst and Isachsen "The large-scale time-mean ocean circulation in the Nordic Seas and Arctic Ocean estimated from simplified dynamics" *Journal of Marine Research*, 2003, volume 61, pages 175-210.

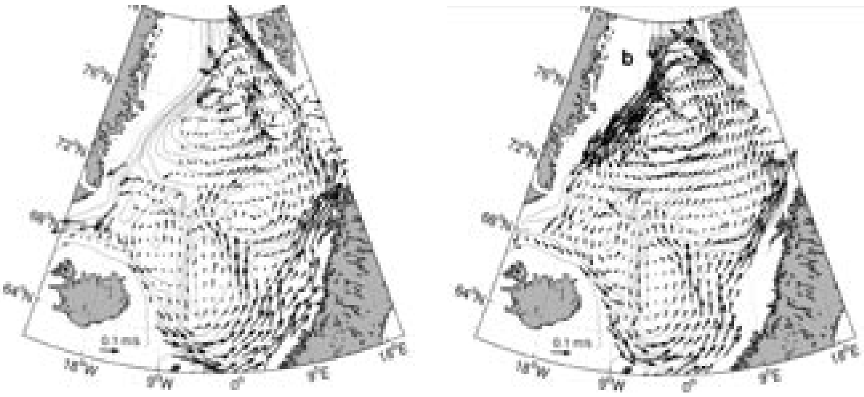


Figure 3. Surface velocities in the Nordic Seas (Jakobsen et al., 2003). The mean surface velocity estimated from surface drifters is shown to the left, while the surface velocity from our simplified model is shown to the right. In general, the agreement between the two is good. The apparent difference in surface velocities east of Greenland is due to the complete lack of surface drifters in this area. Gray lines are contours of constant depth.

Reindeer eyes differ in summer and winter

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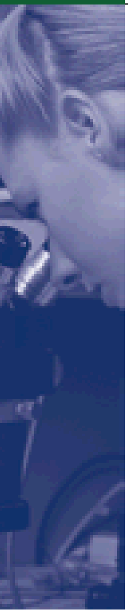
Photo: Nicholas. J.C. Tyler

Polar animals experience photic conditions with either very short or entirely dark days or continuous bright light. This may upset the animals' biological clocks and affect their temporal organisation but permanent light and darkness and the seasonal transition between these extremes may also affect vision more directly. Little is known about how the visual system of mammals responds to the large seasonal differences in luminance experienced at high latitudes, but results obtained in a recent study of reindeer eyes may reflect an important adaptation to such conditions.

Some vertebrates have a reflective structure behind their retina called the tapetum lucidum ("carpet of light"), which is one important adaptation to low levels of illumination. To make maximal use of light, incoming photons are reflected back through the retinal layer of photoreceptors in a "double pass". This may be observed as the light reflected from the eyes of some animals ("cat's eye"). In reindeer there appears to be a dramatic difference in the spectrum of this reflectance between summer and winter (Figure 1).

When bright white light was shone into formalin-fixed eyes obtained from reindeer in winter, the colour of reflected light was deep blue (Figure 2). In the "double-pass" stimulation of retinal photoreceptors this may be explained as favouring night vision. In summer, on the other hand, the reflected light was consistently yellow, apparently favouring daylight vision. There was no such shift between summer and winter in eyes from roe deer. The ambient light of the Arctic winter day is predominantly blue; wavelengths which favour the rods and the short-wavelength cones to be stimulated. It would therefore be "unnecessary" to reflect the longer wave-



lengths that do not appear at this time of year. However, the notion of a reduced reflection when light intensity is low appears counter-intuitive, if the purpose is to enhance photon capture by the receptors. Thus, the functional consequence of these findings is far from elucidated.

The validity of the measurements of spectral reflectance was supported by a change in the structure of the tapetum itself. The reflection from the cat's tapetum is suggested to adhere to "Bragg's law", based upon the spacing of layers of rodlets which diffract, interfere and back-scatter light; like how X-rays are diffracted in a crystal. The microanatomy of the reindeer tapetum shows that in winter there is a larger distance between collagen fibres than in summer. According to Bragg's law, this should shift the reflected light by 28.6 nm, which is very close to the measured ca 30 nm spectral shift (Figure 1).

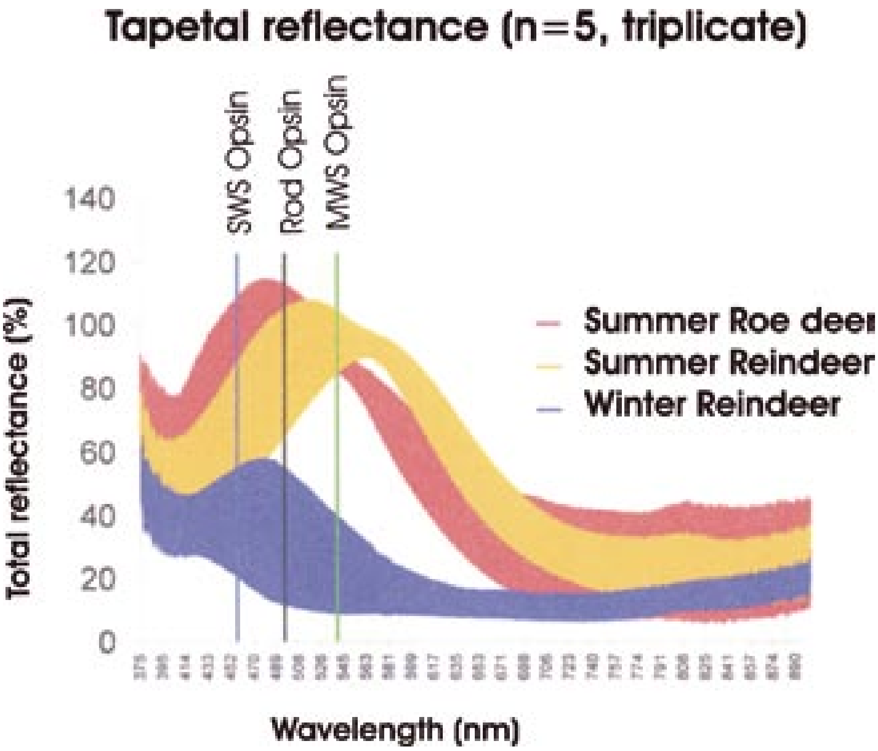


Figure 1. Tapetal reflectance spectra recorded from three groups of eyes; reindeer in summer and winter and roe deer in summer. Data are given as percentage of the total reflectance obtained from a white control. Spectral data are presented with one standard deviation on either side of the mean value for each wavelength recorded. From: Dukes, Van Oort, Stokkan, Stockman, Foster and Jeffery (2003) Seasonal adaptations to LL and DD in the eyes of Arctic reindeer. 33rd Annual Meeting Soc. Neurosci., New Orleans, USA.

Figure 2. Tapetua lucida of reindeer eyes; A6 - mid-winter, B6 – mid-summer. Both eyes have cornea, lens and retina removed. Note the marked difference in the colour of reflected light.

No other studies have been aimed at exploring the visual system of Arctic animals in relation to their extreme photic environment. The present findings are entirely new and unexpected and may reflect an adaptation with consequences that are currently unknown. Thus, it is not known how these changes may affect the reindeer in their natural environment, or if and how man-made artificial changes of the photic environment may interfere with this aspect of the reindeer visual system.

Iceland scallop stocks in the Svalbard area – 20 years after the fishing boom of the 1980s

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When both the cod stock and the capelin stock in the Barents Sea went down in the early 1980s, fishing vessel owners were searching for new unexploited fishing resources. Due to weakness in the Norwegian legislation their choice felt on the poorly documented stocks of Iceland scallops at Jan Mayen and in the Svalbard area. Old purse seiners, trawlers and even supply vessels for the off-shore oil industry were rebuilt for scallop fishery. In addition, 9 new large vessels were built designed for this fishery. All told, 29 large vessels were dredging for Iceland scallops in the Svalbard area from 1985 to 1992. The fishery started at Jan Mayen in 1985 and continued at the bed close to Bear Island, before they moved on to the beds north of Svalbard close to the small island Moffen.

We have no accurate statistics on how many scallops were caught at the different beds since the catch statistics from the individual vessel only provided the quantities produced. We know, however, that a lot of scallops were caught, killed, and discarded.

The landings were close to 1000 tonnes each year except for 1987 when they reached more than 4000 tonnes of scallop muscle. This is equivalent to about 40 thousand tonnes of live scallops. The last scallop dredger left the Svalbard areas in 1992 due to low stocks and low profitability.

The scallop beds in the Svalbard area were monitored annually from 1986 to 1990. The fishery stopped in 1992; there was one survey in 1994 and one in 1996. After that, the beds were not monitored until August 2006. For this monitoring, we use a simple triangular dredge, which is towed for 1.5 minutes. The catch gives us an index of the scallop density as well as age and size composition of the different stocks.

The index of scallop density on the beds at Bear Island and Moffen showed a dramatic drop in the relative density as the fishery went on during the late 1980s. The lowest observed density was in 1996 at Bear Island and in 1994 at Moffen.

The new survey in 2006 shows that the bed at Bear Island has not fully recovered to the density level found at the beginning of the fishery, whereas the Moffen bed is now at the same level as it was in the mid 1980s.

When the fishery started in the Svalbard area in 1986 the scallop stocks at Bear Island and Moffen consisted of large and old scallops. At Bear Island there were no scallops smaller than 50 mm shell height in the 1986 samples, indicating almost no recruitment. Later, in 1996 and 2006 the recruitment seemed to increase significantly, but large scallops still predominated in the population.

The scallops at Moffen were generally smaller than those at Bear Island, and the size distribution showed several small size groups, although the large scallops dominated in all samples. This also indicates a more even recruitment to the stock.

The heavy scallop fishery on the beds at Bear Island and Moffen had severe effects on the scallop density. Both beds appear to be recovering, although the Bear Island bed has not yet reached the scallop density it had before the fishing started. At Moffen the density is almost the same as it was in 1986 and the recruitment seems good in both areas.

We know that dredging for Iceland scallop was harsh on all bottom fauna. This study did not examine the impact on other benthic species commonly found on Iceland scallop beds. To shed light on this question, a more comprehensive investigation is needed.

Killer whales in Arctic Norway: the garbage can of the ocean

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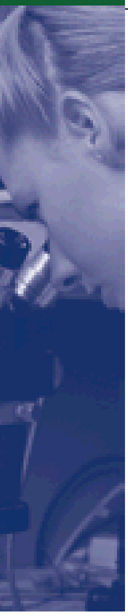
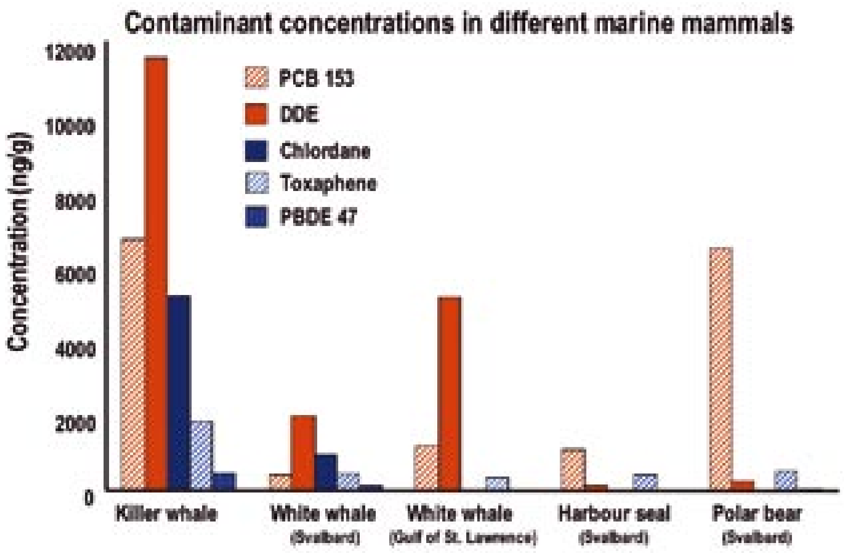
Killer whale. Photo: Hans Wolkers

Marine predators, such as seals and whales, are exposed to relatively high contaminant concentrations. Several studies have indicated that this may result in adverse effects, specifically targeting the endocrine and immune systems. Killer whales (*Orcinus orca*) are widely distributed toothed cetaceans inhabiting all oceans and are true icons of the sea. They are capable of surviving on a variety of prey and different subpopulations are adapted to feeding off the resources available to them in their specific home range. The subpopulations are genetically distinct and differ in various aspects of morphology, vocalization patterns, habitat use, as well as diet. One of the killer whale populations in the North East Atlantic is specialized in feeding on Norwegian spring-spawning herring (*Clupea harengus*). They follow the seasonal migrations of the herring throughout their annual movements in the Norwegian and Barents Seas and are thought to feed predominantly on these fish. It has been estimated that over 1500 killer whales might be present in Norwegian coastal waters when herring is abundant.

Pollution is a continuing threat to the health of both marine animals and humans harvesting the sea. Many chemicals that end up in the Arctic are fat-soluble and resistant to biological degradation. The Arctic marine environment is particularly vulnerable to these pollutants because it acts as a final contaminant sink and consequently contains a major portion of these compounds. Due to bioaccumulation processes, marine predators, such as killer whales, are exposed to relatively high concentrations, possi-



bly leading to adverse health effects. Along North America's west coast, killer whales are highly contaminated with PCBs, dioxins and PBDEs. No data exist on pollution in killer whales from Norway. Therefore, eight male killer whales were sampled using remote biopsy, allowing inferences to be drawn concerning the pollutant loads in a sample of apparently healthy animals. In addition, herring, the killer whale's main food source, was sampled. A comprehensive selection of contaminants was targeted, including PBDEs and toxaphenes.



Chemical analyses of the samples taken reveal a shocking reality: the herring have five to ten times higher levels of contaminants as compared to polar cod from the high Arctic. For the killer whales things are even worse. Massive amounts of pollutants have accumulated in their blubber tissue, even more than in polar bears. This gives killer whales the dubious distinction of being the Arctic predator with the highest levels of contaminants. Compared to other animals from the Svalbard area, killer whales carry substantially higher levels of pollutants. Even the white whales from the Canadian Gulf of St. Lawrence, that are thought to suffer heavily from exposure to pollutants, show substantially lower contaminant levels than the Norwegian killer whales. Particularly striking are the high toxaphene concentrations in the killer whales, indications that the whales and their food spend quite some time in the eastern Svalbard area, notorious for toxaphene pollution. Also brominated flame retardants are well represented.

It is difficult to predict what contaminant-induced effects may result from this toxic exposure, but with levels as high as in the Norwegian killer whales, the risk that the immune system becomes compromised and reproduction impaired is very realistic. Future monitoring and additional studies will be of utmost importance to see how contaminant levels develop over time, and what the effects may be.

Fact box

Killer whales are actually big dolphins and may weigh well over six tons. They inhabit most of the world's oceans – including the Atlantic, Pacific, and Indian Oceans – and are one of the few marine mammal species inhabiting both Arctic and Antarctic waters. They seem to prefer the colder areas, possibly because of the abundance of food. With their characteristic black and white patterns, killer whales are among the best known cetaceans and are true icons of the world's oceans.

Killer whales are amazingly adaptable, and specialize on whatever food sources are locally available, from small fish to large mammals. Even deer and moose have been reported to end their life in the jaws of killer whales. These adaptable creatures are famous for taking advantage of temporary large prey densities, such as during the pupping season of seals in Patagonia or herring spawning along the coast of Norway. It has been estimated that thousands of killer whales might be present in Norwegian coastal waters when herring is abundant.

Along the coast of British Columbia and southern Alaska, different whale populations with different feeding strategies have been identified: "residents" and "transients". Like the Norwegian killer whales, residents stay mainly along the coast and have fish as a major portion of their diet. The transient killer whales frequent coastal waters as well as the open ocean, but their diet consists almost exclusively of marine mammals. Because of their position at the top of the food chain, the health of the killer whale populations can be considered as the ultimate indicator of marine ecosystem health.

Life at the edge – Benthic fauna at the Barents Sea ice edge in a changing climate

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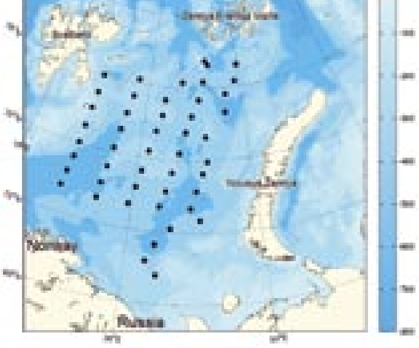
The basket star *Gorgonocephalus eucnemis*, which we found in the northern part of the study area. Photo: Bjørn Gulliksen

Sea ice is a major factor influencing the ecology of the Barents Sea. Ice conditions range from quasi-permanent ice cover in the northern areas to mostly ice-free areas in the south. Reductions in Arctic ice cover and thickness in response to climate change have already been occurring for several decades and are projected to continue.

In the Barents Sea, the annual spring phytoplankton bloom is restricted to a short time window between the start of the spring ice-melt and the formation of new ice in autumn. The duration of ice cover influences the timing of the spring bloom and also the food supply to the organisms living at the sea floor (benthos). Conditions of intermittent ice cover lead to an increased benthic biomass, most likely connected with the short, but intensive spring bloom and short, direct pathways for energy transfer from primary producers to the benthos.

The benthos comprises a range of animal groups, notably bristle-worms, shrimps, prawns and lobsters, starfish, brittle stars and sea-urchins, snails and clams as well as a range of diverse taxa such as corals, bryozoans, sponges, sea-squirts and unsegmented worms. Some of these organisms feed primarily on suspended matter; others dig deep for food. Some are sessile whereas others actively crawl and burrow.

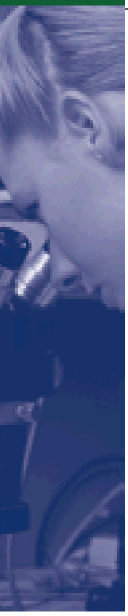


Map of the Barents Sea, showing the sampling stations visited in 2003. Map: Jofrid Skardhamar/Chris Emblow

For the past three years, we have investigated the relationship between the benthic fauna and ice cover, and examined the possible cascade effects that may be expected in the future. The project, financed through the Eastern European programme of the Research Council of Norway, has involved scientists from Akvaplan-niva, Tromsø, the Zoological Institute (ZIN), St. Petersburg, and Murmansk Marine Biological Institute (MMBI), Russia, the University of South Carolina, and Bates College, in Maine, USA, and the University of Tromsø, the Norwegian Institute for Water Research and the Norwegian Polar Institute, all in Tromsø.

All the main faunal functional and taxonomic groups were well represented at most stations, but some trends were evident. Faunal abundance and biomass reached their highest levels in the marginal ice zone, with an average of more than 130 taxa represented by 1760 individuals (maximum around 180 and 2600, respectively). Faunal abundance was lowest in the predominantly ice-covered area,

Sampling of benthic fauna using a modified van Veen grab. Photo: Chris Emblow



with an average of 90 taxa represented by less than 600 individuals. The total biomass varied greatly between stations, depending on the animals present, but values ranged from less than 10 g per m^2 in the predominantly ice-covered area up to 780 g per m^2 in the marginal ice zone.

Preliminary results suggest that the biomass of carnivorous taxa is proportionally higher in ice-covered areas as compared to the other areas. There also was a notable decrease in biomass and abundance of sessile taxa in ice-covered areas relative to areas less influenced by ice, and conversely, a higher representation of motile taxa. This suggests that in predominantly ice-covered areas, where the season during which primary productivity reaches the bottom is limited, there may be an increased "hunting" lifestyle among the benthic fauna.

Longer-term changes in climate are expected to have far-reaching consequences for ecosystems. Generalising our results, we may predict that during warm periods, when the ice edge moves farther north, the area of high benthic abundance also will shift. The area currently most "rich" in fauna may become less so and more "ordinary Atlantic" in character. The opposite scenario might be expected under colder conditions, with benthic fauna becoming less plentiful in the central Barents Sea.

In recent years, there has been increasing interest in petroleum exploitation in the central-eastern and south-eastern part of the Barents Sea, and the proposed Shtokman field is currently located in the marginal ice zone. Sea floor monitoring using benthic fauna could help to distinguish natural faunal variations from variation caused by anthropogenic impacts. Benthic faunal analyses therefore continue to be a useful tool for studying environmental conditions, and play an important role in researching the implications of both climate change and human impacts on ecosystems.

Fridtjof Nansen, the scientist

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Despite the fact that a great deal has already been written about the Norwegian polar explorer and national hero, Fridtjof Nansen (1861–1930), his scientific activity has not to the same degree been the object of systematic, scientific historical research. The point of departure for this work is that science was such a key aspect of Nansen's life, that it is difficult to understand his work and thoughts without viewing them in the light of his professional orientation and his theoretical beliefs. The research project will result in a biography which covers Nansen's entire life, from cradle to grave, and is scheduled for publication by Gyldendal in 2008. The primary research is particularly in the area of Nansen's broad scientific work, and will concentrate on four main areas.

Nansen, the biologist. Through his biology studies, Nansen was a firm believer in evolutionary theory. This was also important for his social viewpoints. It is apparent that at the end of the 1800s, he – like most of his contemporaries – had a pre-Darwinist, Lamarckist explanation of evolution and heredity. But at the turn of the century, Nansen became one of Norway's very first, modern Darwinists. This is important for how Nansen explains heredity, how he interprets human "races", and most importantly how he loses his belief in teleological development.

Nansen, the oceanographer. The *Fram* expedition was very important for developments in several scientific fields in Norway. At the University in Kristiania (Oslo), oceanography was to a large extent built up and developed around Nansen as a person. Textbooks were lacking, but the students themselves participated in the field, under Nansen's guidance. His and Helland-Hansen's studies of the North Atlantic Ocean currents, among other phenomena, have been very important in understanding the climate of the Northern Hemisphere. The development of this field of science, along with Swedish researchers and others, made Scandinavia a world leader in geophysics, with core competence in the so-called Bergen School.

Nansen, the cultural scientist. Nansen's encounter with the Inuit on Greenland (in 1888-89) was a turning point for him. For Nansen, many aspects of the traditional life of the hunter served almost as an ideal, a positive contrast to what he considered to be the moral decline of modern European society. Nansen writes in several contexts about the indigenous peoples of the Arctic, and throughout his life, Nansen was occupied with theoretical questions, such as the roots of Inuit culture. In addition, Nansen launched

Polar hero Fridtjof Nansen, as presented in the biography by W.C. Brøgger and Nordahl Rolfsen.

important methodological theories about the validity of historic sources. In the case of the so-called "saga debate", Nansen did pioneering work in connection with his great opus on cultural history, *In Northern Mists*.

Nansen, the research strategist. Nansen had clear ideas about how Norwegian research should be organized and what should be prioritized on relatively modest budgets. This was the case for the university, as it was for the question of establishing other institutions of higher learning. He expressed his views on the Academy of Sciences, and advocated the establishment of the Institute for Comparative Research in Human Culture. He also argued for developing the academic environment in Kristiania rather than Bergen, for the study of oceanography. Additionally, Nansen had clear opinions about the qualifications of individual researchers. At a time when the allocation of travel grants was often a matter for Parliament, Nansen was consistently contacted by the members of Parliament for his views and opinions.

Fridtjof Nansen was a scientist. His research results from the *Fram* expedition ultimately led to new theories on the attributes of ocean currents.

CliC – an International Climate and Cryosphere Project

The CliC project was established in March 2000 by the World Climate Research Programme (WCRP), and in 2004, the Scientific Committee on Antarctic Research (SCAR), became its co-sponsor. The CliC International Project Office is located in Tromsø and is hosted by the Norwegian Polar Institute, with additional funds provided by the Norwegian Research Council.

What is the Cryosphere?
The cryosphere consists of the frozen portions of the globe. This includes ice sheets, glaciers, ice caps, icebergs, sea ice, snow cover and snowfall, permafrost and seasonally frozen ground, lake- and river-ice. Parts of the cryosphere are strongly influenced by changes in climate, and may therefore act as an early indicator of both natural and human-induced climate change.

Role
CliC encourages and promotes research into the cryosphere and its interactions with the global climate system. It seeks to focus attention on the most important issues, encourage communication between researchers with common interests in cryospheric and climate science, promote international cooperation, and highlight the importance of this field of science to policy makers, funding agencies, and the general public. CliC also publishes significant findings regarding the role of the cryosphere in climate, and recommends directions for future study. CliC not only encourages research activities, but also supports the use of scientific results in developing appropriate policies relating to climate and the cryosphere.

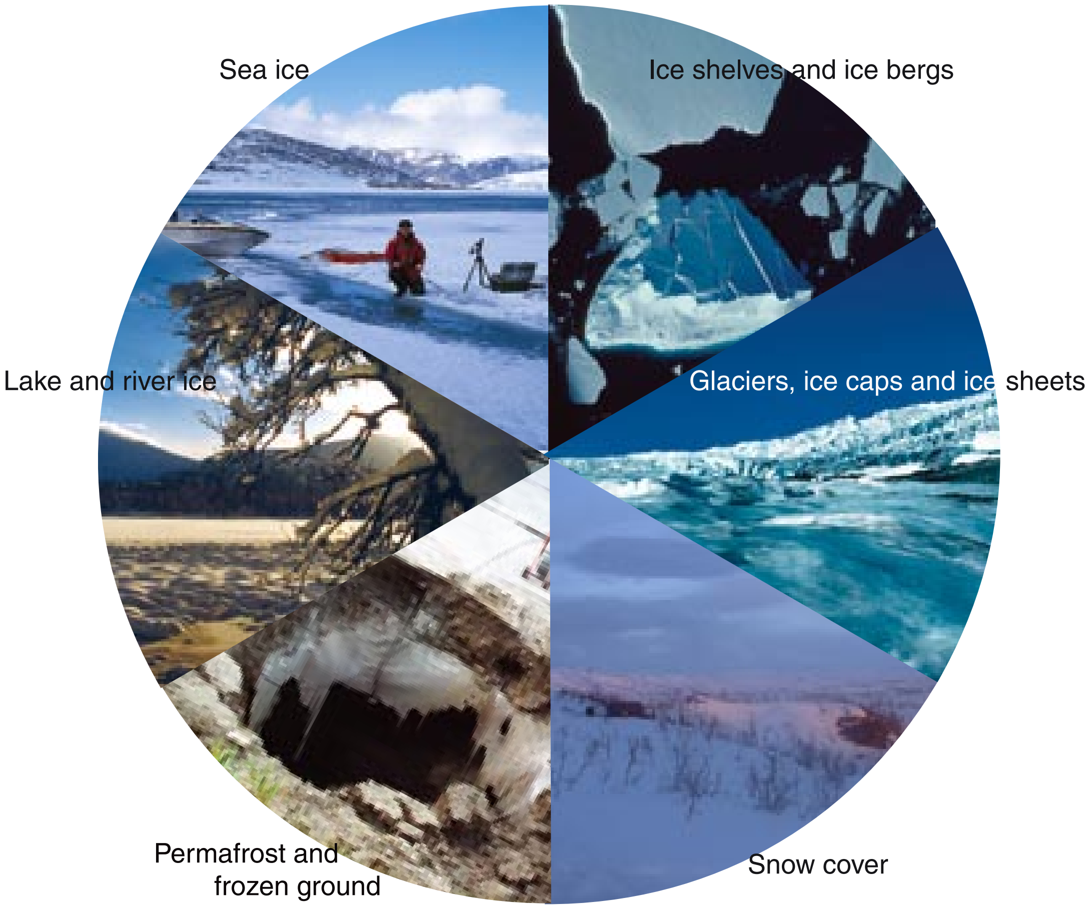
Goal
The project's principal goal is to assess and quantify the impacts that climate variability and change have on components of the cryosphere and its overall stability, and the consequences of these impacts for the climate system.

CliC addresses key scientific questions related to four CliC Project Areas:

1. The terrestrial cryosphere and hydrometeorology of cold regions
2. Glaciers, ice caps and ice sheets, and their relation to sea level
3. The marine cryosphere and its interactions with high latitude oceans and atmosphere
4. Links between the cryosphere and global climate

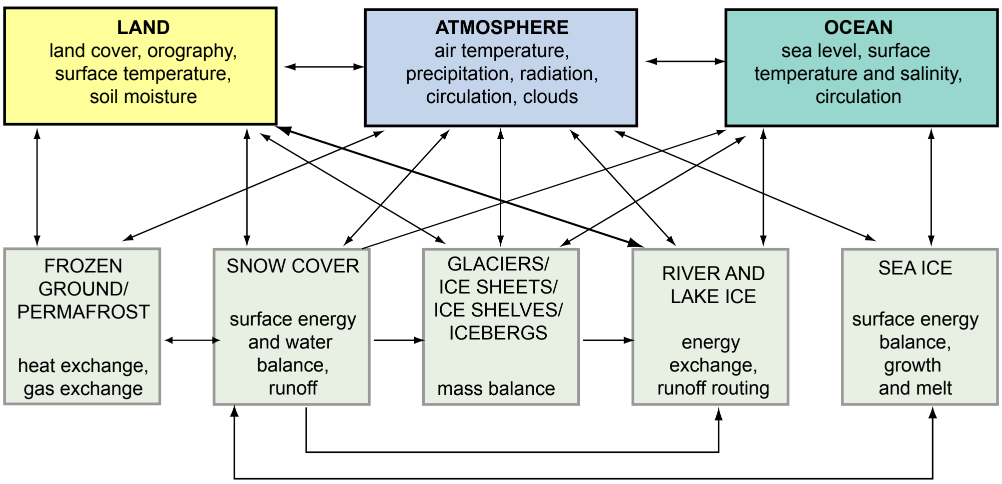
To attain its goal, CliC develops and coordinates national and international activities related to cryosphere and climate. CliC is not a funding agency; however, it provides assistance in organizing conferences, workshops, scientific experiments, and model comparison studies, and collaborates with other groups involved in climate research. Recent workshops sponsored by CliC include workshops on High Latitude Reanalysis, Understanding Sea-level Rise and Variability, and Antarctic Sea-Ice Thickness.

Cryosphere

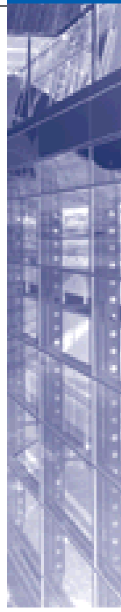


The cryosphere is an integral part of the global climate system, with links and feedbacks influencing energy and moisture fluxes, clouds and precipitation, hydrology, and atmospheric and oceanic circulation. It is important both as an integrator of and influence on climate processes, and as an indicator of climatic change. (Photo composition courtesy Helle Goldman, Sebastian Gerland, Tordis Villinger, Norwegian Polar Institute and Vladimir Romanovsky, UofA, Fairbanks.)

Cryosphere-Climate Interactions



Lists in upper boxes indicate important state variables. Lists in lower boxes indicate important processes involved in interactions. Arrows indicate direct interactions.



Data and Information Service for CliC (DISC)

An example of CliC activities is DISC – a web-based, fully-searchable data and information service for CliC. Its core is a single-point-access, fully-searchable database of information and other data related to cryosphere. DISC also contains metadata that allow researchers to find appropriate cryospheric data sets easily. There is also a list of cryosphere-related meetings and jobs available on the DISC web site at http://clic.npolar.no/disc/index.html.

Another example is the database of specialists who work in cryospheric research. Scientists from all over the globe are encouraged to register their expertise at http://clic.npolar.no/specialists/. The project can then draw on their knowledge to provide expert advice to agencies, panels, and other groups interested in climate and cryosphere. At this writing, 272 scientists have registered their willingness to contribute to CliC.

The Tromsø location for CliC is ideal for interacting with many of the other Norwegian polar research programs. For more information, visit the CliC web site http://clic.npolar.no.

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Norway and the International Geophysical Year 1957-58

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Norway station expedition to Antarctica 1956-60. A well-earned break on the way to the mountains. Photo: Torgny Vinje, Norwegian Polar Institute

During the International Polar Year (IPY) which begins in 2007, there will be a great focus on polar research all over the world, not least in Norway. Worldwide coordinated scientific efforts like this one have been launched three times before: in 1882-83, 1932-33 and 1957-58.

In 1882-83, Norway's main research station was situated in Alta in northern Norway and was led by geophysicist Axel Steen, who had a great interest in the earth's magnetism. In 1932-33, the Norwegian authorities could not afford to organize an independent Arctic expedition, and the scientists had to make use of existing stations and observatories. Norwegian scientists contributed geophysical data from Svalbard, East Greenland and the Norwegian mainland, and observations were also made at whaling stations in the South Atlantic Ocean.

During the two first international scientific years, Norway concentrated its efforts in the Arctic, but in 1957-58 the main focus was in Antarctica. Why was that?

In 1939, Norway annexed a large land area in Antarctica: Dronning Maud Land. The annexation and the claim for sovereignty were partly motivated by Norwegian commercial interests (whaling) and partly by Norwegian expansionism. The claim for sovereignty demanded a Norwegian presence in Antarctica, so that others did not claim the same area.

Norwegian whale catches decreased after World War II because whale stocks had been depleted, and in the 1950s the ship owners realized that the industry would soon be unprofitable. With whaling out of the picture, one of the motivations for the Norwegian claim for sovereignty was gone.

The other motivation was science. The scientific activity was closely tied up with politics. Since the end of the 19th century, Norwegian contributions to international polar research had secured the country admission into the exclusive club of polar nations alongside Great Britain, Sweden and Russia. Norway was particularly involved in research in Svalbard and organized annual expeditions under Norway's Svalbard and Arctic Sea Research Body, the forerunner of the Norwegian Polar Institute.

One of the reasons why Norway was a force to be reckoned with in the polar regions was that neither the Arctic nor the Antarctic had been seen as strategically important by the Great Powers. World War II and the Cold War changed that view. As a consequence, Norway's freedom both in the north and south was greatly restricted. Norway had to pay even greater attention to what the influential nations were up to. We see a clear example of this in the International Geophysical Year (IGY) in 1957-58.

The founding of the Norwegian Polar Institute in 1948 gave a new boost to Norwegian polar research. The internationally acknowledged scientist Harald Ulrik Sverdrup was called home from the US to lead the institute, and a Norwegian-British-Swedish expedition was sent to Antarctica. The Maudheim expedition did pioneering mapping work in Dronning Maud Land, which strengthened Norway's claim for sovereignty.

After the Maudheim expedition, Norwegian authorities were more restrictive with funding for polar research, and the scientists concentrated their limited resources to the Arctic. For the International Geophysical Year in 1957-58, the Norwegian Polar Institute had no plans to conduct research in Antarctica. When this became known in October 1954 it led to consternation both in the US and at the Norwegian Ministry of Foreign Affairs. The Polar Regions were of great strategic importance and the West could not leave a void that could be filled by the Soviet Union. The Norwegian Minister of Foreign Affairs, Halvard Lange, advocated launching a large Norwegian expedition to Antarctica during IGY in 1957-58, and succeeded in his aim.

Against this backdrop, the Norwegian Polar Institute equipped the Norway Station expedition (1956-60) led by Sigurd Helle. As with the Maudheim expedition, the main objective was mapping in Dronning Maud Land. The Norway Station expedition made several scientific findings, but even more importantly it manifested Norway's role as a polar nation in the Antarctic. In 1957, the twelve countries that had activities in Antarctica during IGY agreed to form the Special Committee on Antarctic Research (SCAR). Thanks to Norway Station, Norway remains a key nation in the administration of the continent.

IN BRIEF

Political initiatives

Chairmanship of the Arctic Council passed from Russia to Norway in October 2006. The Arctic Council is "a high-level forum for cooperation, coordination and interaction between Arctic states, indigenous communities and other Arctic residents". Under the Norwegian chairmanship the programme will focus on some of the key challenges facing the Arctic region. Among the most important are climate change and integration of resource management. The Arctic Council Secretariat will be established at the Norwegian Polar Institute in Tromsø during spring 2007. See www.arctic-council.org

An Integrated Management Plan for the Norwegian Sector of the Barents Sea was presented by the Norwegian Prime minister in March 2006. The plan describes the environmental conditions for a sustainable use of the ocean, as well as political priorities. The Norwegian Polar Institute led the work on the scientific basis for the plan, together with the Institute of Marine Research. Both institutes have been given central roles in further work that will lead to a revision of the plan in 2010.

New teaching initiatives

A new course in Arctic Biology has been introduced at the University of Tromsø. The 10-credit course, given by the staff of Department of Arctic Biology/Department of Zoophysiology, deals with the abiotic conditions that dictate the climate in Arctic regions and gives a description of the distribution and general biology of all resident and the most prominent migratory animals of the Arctic, and how they are adapted to cope with the challenges of their austere environment. The course uses the textbook by A.S. Blix, presented below.

The University of Tromsø is establishing a new PhD school within the field of community medicine. Under the name EPINOR (EPIdemiologiske studier av miljø, livsvilkår og helse i NORdområdene), the PhD school will focus on epidemiological studies of the environment, living conditions and health in the North. Particular emphasis will be placed on Norwegian–Russian research cooperation.

New books

Einar-Arne Drivenes and Harald Dag Jølle, both at the Department of History at the University of Tromsø, have prepared an abbreviated English version of their three-volume opus "Norsk polarhistorie" called "Into the Ice. The History of Norway and the Polar Regions". Like the longer work on which it is based, the new book presents Norwegian expeditions and research in polar regions. Both Statoil and the Norwegian Research Council have showed interest in producing special editions of the work with their own forewords.

A new edition of "Birds and Mammals of Svalbard" has appeared in English and Norwegian versions. Number 13 in the Norwegian Polar Institute's Polar Handbook series, the book is edited by Kit M. Kovacs and Christian Lydersen. It provides updated information on wildlife in Svalbard – the distribution, general ecology, life history and reproduction of each species as well as management status. There is also a chapter on conservation and the rules and regulations that are in place to protect Svalbard's unique wilderness.

Arnoldus Schytte Blix, director of the Department of Arctic Biology at the University of Tromsø, recently published a book entitled "Arctic Animals and their Adaptations to Life on the Edge". This book answers the questions: Where and what is the Arctic? What animals live there, and how are

Doctorates in polar studies at the University of Tromsø

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Margje Post
The Northern Russian pragmatic particle dak in the dialect of Varzuga (Kola Peninsula): An information structuring device in informal spontaneous speech
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Dr. med.

Maria Jurievna Averina
A population based study on cardiovascular diseases in Northwest Russia. The Arkhangelsk study 2000 (2005)
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Dr. philos.

Steinar Pedersen
"Lappekodisillen i nord 1751-1859 - Fra grenseavtale og sikring av samenes rettigheter til grensesperring og samisk ulykke"
Address: Buolbmát/Polmak, N-9845 Deatnu/Tana

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Matthias Forwick
Sedimentary processes and palaeoenvironments in Spitsbergen fjords (2005)
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Carsten Hvingel
Construction of biological advice for the management of a northern shrimp fishery – the West Greenland example (Joint supervision with the Institute of Marine Research)
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Morten Johansen
Juvenile salmon and aquatic invertebrates in northern Norway (2005)
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Marit Sjo Lorentzen
The molecular basis for cold adaptation of catalase from the psychrophilic marine bacterium *Vibrio salmonicida* (2005)
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Geir Rudolfsen
Sperm competition, cryptic female choice and offspring viability in external fertilizing species
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Steinar Thorvaldsen
Statistical and bioinformatical analyses of protein sequences from cold marine environments. A comparative study of alignments
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Arild Vaktskjold
The quality and use of two health registries in Russia (2005)
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Margrethe Aanesen
To Russia with love? Four essays on public intervention under asymmetric information: the Petsjenganikel case on the Kola Peninsula
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PhD

Kari Sire Berner
Variability of the two main branches of the North Atlantic Drift through the Holocene (Joint supervision with the Norwegian Polar Institute)
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Jonathan Verreault
Organohalogen contaminants of established and emerging environmental concern in Arctic Glaucous Gulls: associations with endocrine status and basal metabolism (Joint supervision with the Norwegian Polar Institute)
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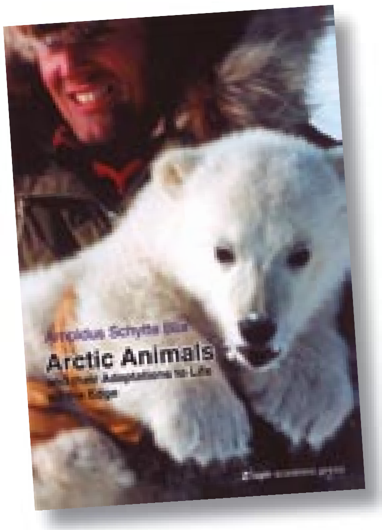

they distributed? How do they cope with cold in their austere environment, and how can Arctic mammals survive birth when it is 40 degrees below freezing? How can seals dive to a depth of 1000 metres and stay submerged for more than one hour, and how does complete darkness in winter affect the inhabitants of the high Arctic? The book is based on the author's 40 years of experience in the Arctic, its environment and animal life. As this book contains almost 200 illustrations and deals with the entire Arctic animal kingdom, it is suitable as a textbook for courses in Arctic biology, and also serves specialists in the field. It is a reference book and a source of information about published original literature.

Paul Wassman at the Norwegian College of Fishery Science has edited a book entitled "Structure and Function of Pan-Arctic Food Webs: A First Overview". The book was published as part of the series *Progress in Oceanograpy* Volume 71, pages 123-477.

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