FRAM CENTRE

FRAM FORUM 2015

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OLD NEWS IS BAD NEWS

In January, reports from two highly respected United States government agencies were in the news. The National Climatic Data Center at the National Oceanic and Atmospheric Administration (NOAA) and the Goddard Institute of Space Studies at the National Aeronautics and Space Agency (NASA) reported that 2014 had been "the warmest year on record". The institutes had analysed temperature data from thousands of weather stations, ships and buoys deployed at sea and research stations in polar regions. They performed their calculations independently, using slightly different algorithms and reference periods, but both arrived at the same conclusion: 2014 was the warmest year since record-keeping started back in 1880.
But was it really news? It all sounded strangely familiar. Hadn't we heard this before? The headings from a few of NOAA's press releases tell the story:

- 2014 was the warmest year on record (16 January 2015)
- 2012: Warmest year on record (9 January 2013)
- NOAA: 2010 tied for warmest year on record (12 January 2011)
- Past three decades warmest on record (3 September 2010)
- 1998 warmest year on record, NOAA announces (11 January 1999)

So, yes, we *have* heard this before. The news - the bad news - is that we're hearing it again.

Nine of the ten warmest years on record have occurred since 2000. Last year was the 38th year in a row with a global temperature above average. Total snow cover is down. Arctic sea ice is down. Extreme weather events are up. In an unprecedented move, the United States Senate recently voted that global warming is real, though many senators are still not convinced that human activities are causing it.

The NASA and NOAA reports both mentioned El Niño, a cyclic phenomenon that has been going on for hundreds of thousands of years, independent of what humans have been doing. During an El Niño event, the surface of the Pacific Ocean off the coast of South America is unusually warm, and this raises the global mean temperature. The disturbing fact is that the 2014 temperature record was set despite the absence of El Niño conditions: temperatures in the eastern equatorial Pacific Ocean were normal.

In many other places, however, the oceans were warmer than usual. Both reports cited high ocean temperatures as a factor in raising mean temperatures last year. In fact, NOAA wrote: "In 2014, the warmth was due to large regions of record warm and much warmer-than-average temperatures in parts of every major ocean basin," and went on to list "the northeastern Pacific Ocean in and around the Gulf of Alaska, much of the western equatorial Pacific, parts of the western North Atlantic and western South Atlantic, and much of the Norwegian and Barents Seas."

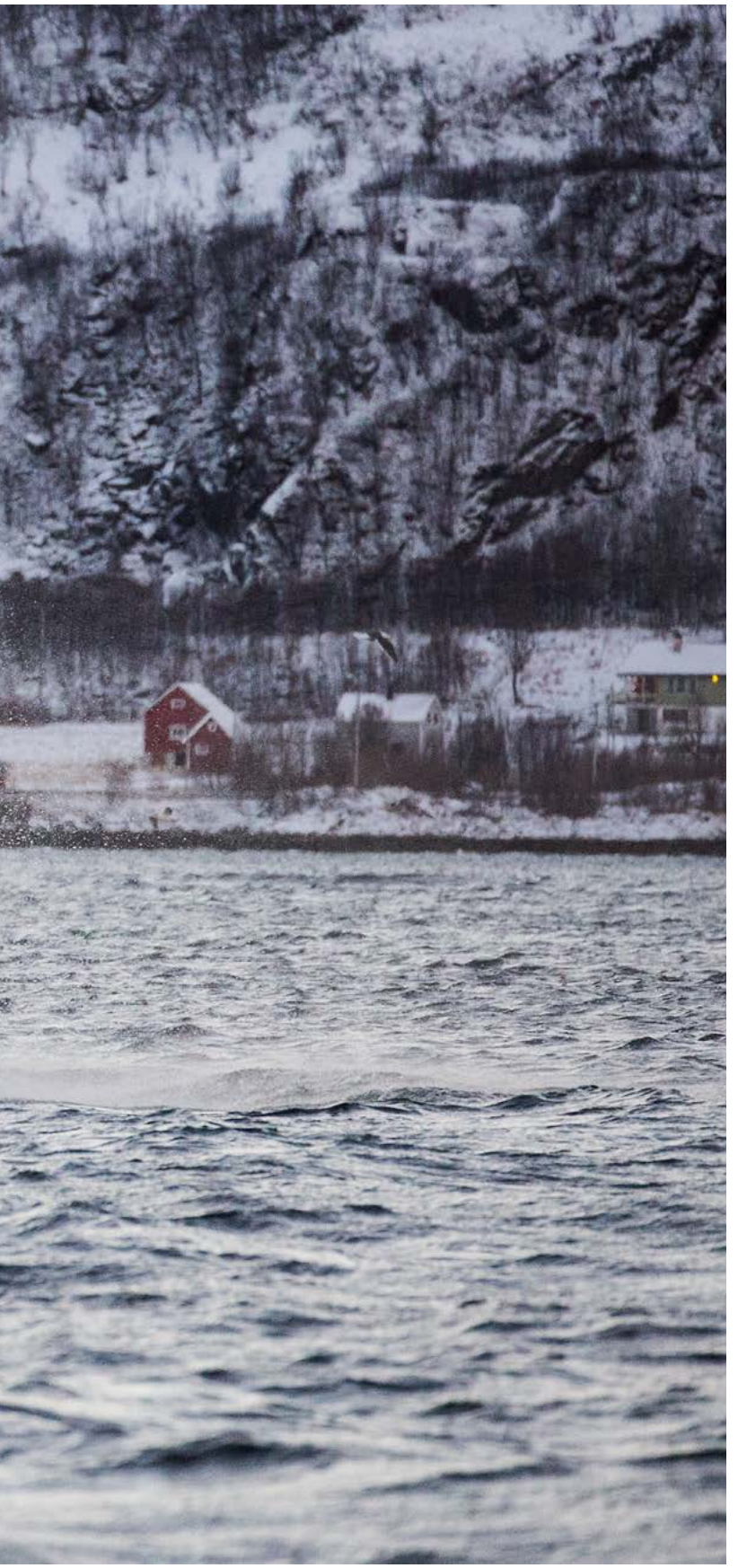
We who live in the High North are seeing these changes in our own back yard. Little wonder, perhaps, that climate change is a recurring theme in Fram Forum.

Many of the articles in this year's issue were written by researchers who study our changing world from a wide variety of perspectives. Some collect data about factors that contribute to changes in the environment, such as deposition of black carbon or release of methane hydrates. Some attempt to predict changes by developing and refining computer models for sea ice, contaminant transport, or entire ecosystems. Others focus on how vegetation reacts to alterations in temperature and rainfall patterns, or to increasing pressure from a growing goose population. Some look ahead and consider the implications an ice-free Arctic Ocean might have for fisheries and shipping.

Clearly, scientists at the Fram Centre are producing important new knowledge. But knowledge must be disseminated before it can be used. That brings us to another group of Fram Centre researchers represented in this issue of Fram Forum - those who are involved in developing ways to keep citizens and decision-makers updated and well-informed about developments in the environment.

Fram Forum is also a way of keeping people informed. Since this is our fourth issue, that's old news. But in this case, we hope old news is good news.

Janet Holmén, Editor



Picture of the year

Three or four years ago the herring changed its migration route along the coast of northern Norway. In November, masses of herring now gather in the outer fjords of Kvaløya, the island just west of Tromsø. This bounty naturally attracts fishing boats, but also many humpback whales, orcas, and fin whales. The whales, in turn, attract human spectators, delighted to have an opportunity to see these huge mammals just a stone's throw from town. The first weekends after the whales arrived in November 2014, so many people wanted to see the spectacle that there were traffic jams on the roads.

In mid-November, I set out in a boat with two other nature photographers to try to capture the drama. With less than a week remaining until the sun went down for good, leaving only winter twilight, the light we had at our disposal was dim and the day was short.

We had been out for a couple hours, and I was only mildly pleased with the pictures I'd taken, but we had to head for home. Near the village on Vengsøya we came across several humpback whales close to shore and decided to try to take photos of them. After we arrived, nothing happened for quite some time, but I kept my camera ready. Suddenly one of the humpbacks jumped straight out of the water a few dozen metres from our boat. Patience and quick reflexes paid off and I caught the gigantic leap on my camera. But it wasn't until I arrived home and downloaded the images that I realised I had captured a truly exceptional moment.

Text and photo: Karl-Otto Jacobsen

All photos: Ole Magnus Rapp

Ole Magnus Rapp

The blueberry girl

An ice-cold wind blows round the corners of the building at Holt. Outside it is morning, but still dark. Inside the climate laboratory, Laura Jaakola is thriving and controlling the climate, getting it just how she wants it for her plants.

THE RESEARCH LEADER at the climate laboratory at Holt research farm in Tromsø is passionate about the plants in the High North, especially the wild berries. If she has to choose, the blueberry is her favourite. Blueberries contain substances that the body needs; the berries are beautiful, available and free. And picking berries takes you out into the countryside and provides exercise, something that Laura Jaakola is also enthusiastic about.

Wild berries have been her job for at least 20 years, and the 46-year-old has a well-regarded doctorate in the subject. Her research results attract attention, and many people both in Norway and abroad are keen to collaborate with her on new projects.

Both Bioforsk (the Norwegian Institute for Agricultural and Environmental Research) and the Arctic University of Norway at Tromsø are involved in the climate laboratory, and Laura also divides her time between these two collaborating institutions.

In her office hang superb photographs of the Finnish countryside. One shows a brown bear surrounded by pines in a forest, and in the picture, Laura the scientist spies some fine wild berry country - for bears, too, like blueberries. Through the window there is a beautiful view of the island of Kvaløya. Laura and her husband, Ilkka, enjoy going there, she goes to hunt for berries, he goes to seek out some good photographic subjects. They are both lovers of nature and the outdoors, and often spend the night camping under the open sky.

Laura's photographer husband has taken the pictures of the brown bear in the Finnish forest, and has also made a Finnish calendar with images of the dazzling Northern Lights, as well as scenes from Norway. And when the big whales came swimming close to Kvaløya, he was there at once with his long telephoto lenses.

"There is so much beauty here. Exciting landscapes, jagged mountains and fjords. Very different from what we are used to in Finland," Laura smiles.

Finnish Laura is glad that the opportunity to do research in Norway turned up via a colleague from Tromsø. And glad that her husband was willing to join her. Their two grown-up sons have already flown the nest, and are happy to see Mum and Dad enjoying their new existence in the High North.

For many Finns, making it right up to the Arctic Ocean is something really special. Since what must be virtually time immemorial, Finns have been migrating northwards. The High North was always the place of opportunities and challenges, the place that offered a future. Finnish workers laboured in the mines, took part in the fisheries and were skilled seal hunters. Now the Finns are making a name for themselves as entrepreneurs and in academia, they are sending excellent skilled workers and professionals northwards with their enthusiasm and dedication, strong work ethic and *sisu* (a Finnish word meaning stamina or perseverance).

And just about two years ago, along came Laura Jaakola, the blueberry girl, who, with her outstanding academic background and bubbly, contagious sense of humour, is teaching us more about all our wild berries.

"Among other things, blueberries contain antioxidants, which have positive effects on our cardiovascular and blood systems. These substances can also help prevent dementia and Alzheimer's disease," says the research leader and hopes that new knowledge about berries can make even more people want to pick them and to eat nature's own health-bringing substances.

The further north in the world the blueberry grows, the more of these good substances it contains. The reason for this is not quite clear, but may be genetic. Jaakola and her colleagues have namely taken blueberry plants from a number of places and moved them south, all the way to Germany, and put them in the laboratory - and the northern plants have done exceptionally well under otherwise equal conditions.

"The climate of Northern Norway also has the same effect on green vegetables and root vegetables such as swede. The vegetables are healthier, better and crisper," she explains, referring to research done by her colleagues at Bioforsk.

The fact that it is light 24 hours a day in summer may have significance for the quality of berries and vegetables. But the temperature in the High North can also have an effect, and a summer that is a few degrees warmer is not necessarily a plus.

In the climate laboratory, the scientists can set the desired temperature, light intensity and quality, humidity, CO_2 and much more. Here it is possible to create potential climate change scenarios and to monitor how and whether the plants react.

"Knowledge about what is likely to happen to our plants in a different climate reality is extremely important. Will the quality be affected? Or the nutritional content? Will any of our important food plants be threatened?" asks Laura Jaakola.

Her advice to everyone in the High North is that they should pick more blueberries, eat them, and perhaps do as the Finns do: dry the berries and eat them as snacks.

And another aspect of her berry-picking trips that Laura Jaakola likes is that she meets other people. Over a bucket of berries one quickly finds something to chat about. She thinks people are easy to come into contact with, and likes the open, inclusive and interested tone amongst the folk of the High North.

The research community in Tromsø she also describes as inclusive, and academic stimulus is easy to come by. The cooperation in the Fram Centre she finds very stimulating. When two different researchers meet, it often ends up in a joint project no-one could have envisaged before. At the same time, she sees the potential for much more cooperation, preferably multidisciplinary.

Laura is originally from Turku in Southern Finland, but studied and worked in the Finnish city of Oulu. The University of Oulu can take a lot of the credit for Nokia's success, and has invested heavily in new technology. Now Jaakola can see big possibilities for forging stronger links between the Oulu research community and Tromsø, and she would be happy to act as a link and an opener of doors.

Many of her friends in Finland are envious of the Jaakola family's new adopted home town.

"We live in the middle of Tromsø," she says, "and within a radius of a 10-minute drive we have a modern and urban city centre, we have an extremely interesting research community with knowledge that is some of the most advanced in the world, we have floodlit ski trails, and we have both the Tromsdalen valley and Kvaløya. First-class walking and skiing country, with lots of wonderful berries," she says.

Åshild Ønvik Pedersen and Virve Ravolainen // Norwegian Polar Institute
Ingunn Tombre // Norwegian Institute for Nature Research
Helen Anderson and René van der Wal // School of Biological Sciences, University of Aberdeen, UK
Jesper Madsen // Department of Bioscience, Aarhus University, Denmark
James DM Speed // University Museum, Norwegian University of Science and Technology, Trondheim, Norway

Grubbers on the Svalbard tundra: Why do we need monitoring?

The pink-footed goose population breeding in Svalbard has increased dramatically over the last few decades. The population increase, corresponding range expansion and a changing climate suggest a substantially increased potential for disturbance of the Svalbard tundra caused by grazing geese. This calls for monitoring of the pink-footed goose population and its impact on the tundra landscape.

Geese are migratory keystone herbivorous species in the Svalbard tundra ecosystems. They utilise the fragile arctic tundra in the short summer season. The population of pink-footed geese has increased substantially from 15 000 individuals in 1965 to around 80 500 in 2012/2013. This increase is due to a combination of factors such as conservation efforts, intensified agricultural practices providing more food for the geese and, particularly over the last decade, a warmer climate on the breeding grounds.

PINK-FOOTED GOOSE GRUBBING

Upon arrival in spring, the pink-footed geese grub for several weeks for belowground plant parts such as roots and rhizomes. In this early spring period, up to 90% of the goose's diet consists of belowground plant material. Such grubbing may lead to tundra disturbance because the geese create holes and pull away moss cover to access nutritious vascular plant storage parts, thereby reducing plant cover. Where grubbing is sufficiently intensive, this can create small ponds and vegetation-free craters, eventually disturbing the top layer of soil and increasing carbon losses from the tundra.

For the last decade we have focused on issues related to the increasing pink-footed goose population and the impacts of goose grubbing on the Svalbard tundra. The first study, published by Speed and co-workers in 2009, investigated the geographical and topographical distribution of goose grubbing in the Svalbard tundra ecosystem. That study related the extent and intensity of goose grubbing to habitat type (pink-footed geese showed a strong preference for grubbing in wet habitats in low-lying landscapes) and landscape configuration (extent of wet habitat), ultimately predicting that 6.3% of the non-glaciated landscape in Svalbard

Photo: T. Nordstad, Norwegian Polar Institute

would be suitable for grubbing. This is a considerable proportion, given that only 15% of Svalbard's total land area is covered by vegetation.

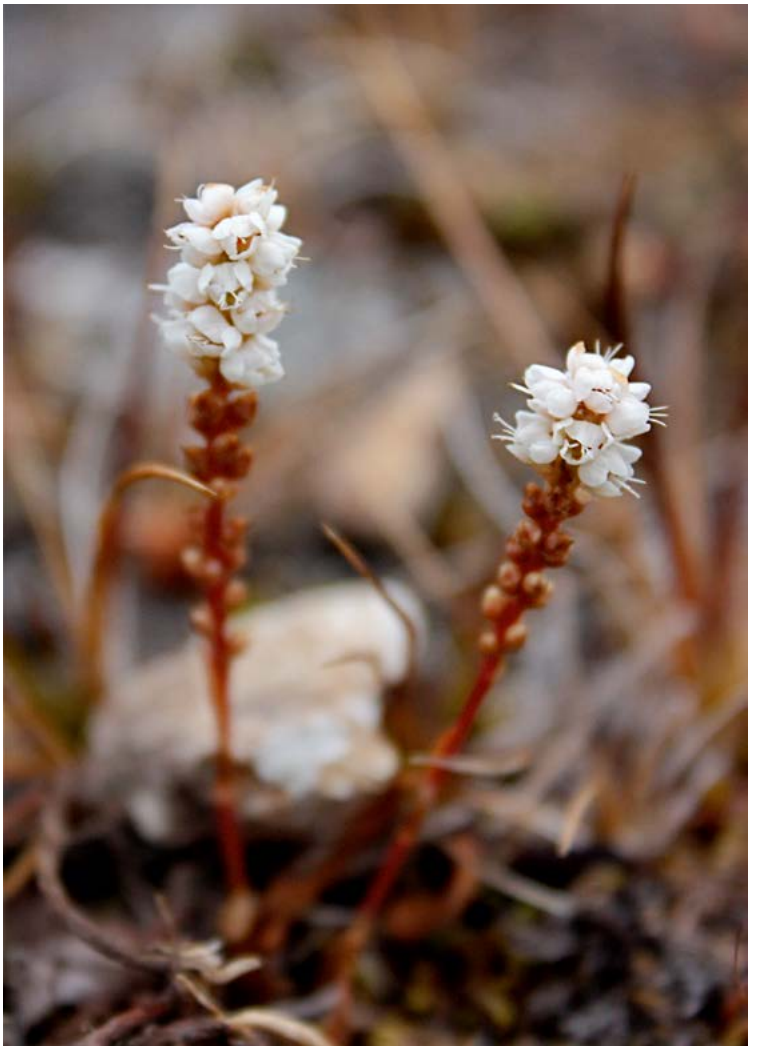
Our most recent study indicates the importance of different drivers of grubbing, such as snow cover, population size and habitat type. Late snowmelt, with extended snow cover, may reduce grubbing because the tundra is protected by snow; however, an increasing population size may lead to more widespread grubbing, particularly in wet habitats, which are the preferred feeding areas because they represent a superior food resource. Given that the consequences of grubbing vary among years and habitat types, the tundra sustains an ecological system that needs continual monitoring. Identification of the drivers of grubbing, and their magnitude under various environmental conditions is important when monitoring and managing the goose population and the Svalbard tundra.

GOOSE GRUBBING IN AN ECOSYSTEM PERSPECTIVE

The arctic tundra is characterised by low productivity and slow recovery from disturbances. How quickly a grubbed area recovers depends on habitat type, snow cover in spring and the degree of grubbing. Interactions between species are likely to change as they increasingly compete with and facilitate for each other. In addition, predator populations grow or shrink with changes in climate. Increasing abundances of geese may have impacts on plant communities, which in turn affect the endemic tundra herbivores, the Svalbard rock ptarmigan and the Svalbard reindeer. Hence, integrated monitoring from an ecosystem perspective will be useful.

ECOSYSTEM-BASED MONITORING

Ecosystem-based monitoring targets components (i.e. species or functional species groups), processes and



functions in an ecosystem that are crucial for overall ecosystem integrity, stability and resilience. The adaptive ecological monitoring framework provides the most developed scheme for implementing such an ecosystem-based monitoring approach.

In 2013, The Fram Centre launched the scientific plan "COAT - Climate-Ecological Observatory for Arctic Tundra", outlining a substantial expansion of on-going monitoring in high-Arctic Svalbard and the low-Arctic Varanger Peninsula in response to international calls for ecosystem-based climate impact observatories in the terrestrial Arctic. COAT is a system for long-term adaptive ecosystem monitoring based on food-web theory, and aspires to be a comprehensive and management-relevant long-term program for the terrestrial Arctic. In Svalbard, the COAT team has developed unique working modules, with one focused on geese (see fact box).

Alpine bistort (*Bistorta vivipara*). Pink-footed geese feed almost only on below-ground overwintering organs of grasses and horsetails at the spring pre-breeding staging sites, but in drier patches the alpine bistort is a favourite to grub. Newly hatched chicks of the endemic Svalbard rock ptarmigan feed exclusively on the bulbils of the alpine bistort and are entirely dependent on access to this resource at the right time of their life-cycle.

Photo: A.-K. Balto, Norwegian Polar Institute

Pink-footed goose grubbing for below-ground plant parts (roots and rhizomes) leads to beak-sized holes in the tundra and fragmentation of the vegetation cover, which may create ponds and vegetation-free craters.

Photos: C. Hübner, Å.Ø. Pedersen, I. Tombre

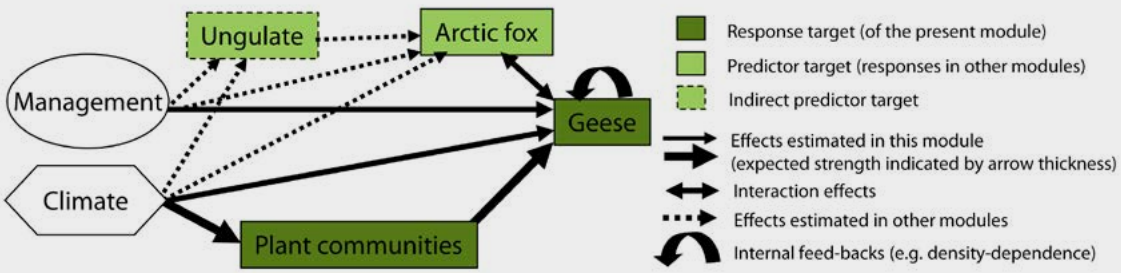
HOW TO MONITOR GOOSE GRUBBING?

The intensity and extent of grubbing may be addressed through two complementary monitoring designs, both implemented in the COAT working module: 1) the goose targeted approach (on-going by authors) where grubbing is monitored in the central staging and nesting areas; and 2) the landscape approach where goose grubbing is assessed on a larger spatial scale in habitats characterised by contrasting abundance levels of both geese and other herbivores. These designs incorporate the important drivers of grubbing and contrasts in population abundances of the herbivores. Currently, we lack precise information on the overall distribution of pink-footed geese in Svalbard, particularly in the eastern areas. As climate continues to warm, these areas will become more attractive to geese, potentially fuelling further population increases and expanding the spatial scale of grubbing. Through continued monitoring of geese and the tundra vegetation we aim to capture these developments and integrate them into management plans for pink-footed geese in Svalbard.

Data sampling of pink-footed goose grubbing along transects near nesting sites of pink-footed geese in Sassendalen.

Photo: H.B. Anderson

Helen Anderson currently works at the Department of Arctic and Marine Biology, UiT The Arctic University of Norway



COAT CLIMATE IMPACT PATH MODEL PREDICTIONS

The figure illustrates the *COAT climate impact path model* for the response targets - the geese (pink-footed goose and barnacle goose) and grazed plant communities. Associated predictor targets are linked to interacting plant communities and predator abundance levels.

For pink-footed geese the main direct ***climate impact path*** is expected to act through earlier onset of spring, opening suitable nesting habitat and leading to increasing densities and a wider altitudinal and geographic distribution. Increasing densities of pink-footed geese are expected to result in increased grubbing with negative consequences for vulnerable tundra habitat and secondary effects on other tundra herbivores. Arctic fox predation affects the survival of geese and predation pressure is expected to increase with the formation of more and larger colonies. For the pink-footed goose one ***management*** action to ensure against increasing tundra degradation is to stabilise the population. According to the newly implemented "AEWA International Species Management Plan for the Svalbard Population of the Pink-footed Goose" the four range states have agreed to work towards stabilising the population at a target of 60 000 individuals as a sustainable long-term population size.

FURTHER READING

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SEE ALSO

http://pinkfootedgoose.aewa.info
http://goosemap.nina

Polar bear cubs have higher levels of pollutants in their blood than their mothers.

Photo: Heli Routti, Norwegian Polar Institute

Heli Routti // Norwegian Polar Institute

Pollutants in polar bears and other arctic animals

Although the Arctic is remote from industrialised areas, numerous man-made chemicals are found at high concentrations in the apex predators of arctic ecosystems: polar bears, arctic foxes, glaucous gulls and ivory gulls.

Persistent organic pollutants (POPs), one class of these man-made chemicals, are produced as pesticides or industrial chemicals and are highly persistent in the environment. They are transported over long distances from southern industrialised areas to the Arctic by winds and ocean currents. Once in the Arctic, they tend to biomagnify in food webs, ending up in top predators. Various health effects such as changes in hormone systems and reduced capacity for immune defence have been associated with high contaminant exposure. In worst cases, these effects may reduce the reproductive potential of arctic top predators.

SOME CHEMICALS ARE REGULATED, BUT ARE THEY DECREASING IN ARCTIC ANIMALS?

Both use and production of POPs (such as polychlorinated biphenyls (PCBs), dioxins, many organochlorine pesticides and a few brominated flame retardants and perfluorinated substances) are banned or restricted by the Stockholm Convention, an international treaty under United Nations Environment Programme. Although the concentrations of several POPs that have been banned for a relatively long time have decreased in the arctic environment during the last decades, they still make up a major portion of the pollutants found in arctic animals. Temporal changes of POPs are not only influenced by emission patterns and regulatory processes, but also by climate variability. Changing climate may affect transport of pollutants from southern areas. Furthermore, scientists expect that POPs deposited in long-term sinks, such as water and ice, will re-volatilise into the atmosphere due to rising temperatures. Warming climate in the Arctic may also lead to changes in food web structures. This may in turn affect exposure to pollutants in arctic species. Increase in pollutant exposure due to changes in food web structure has already been documented in polar bears from the Canadian Arctic.

ARCTIC ANIMALS ARE EXPOSED TO A COCKTAIL OF CHEMICALS

In addition to “legacy” POPs, a number of chemicals that are still in use have been detected in arctic predators. These compounds share properties with POPs and have potential to be transported over large distances, biomagnify in food webs and lead to toxic effects. For example, products designed to replace the banned brominated flame retardants, and some compounds used in plastic have been found in arctic

Biopsies of fat tissue from polar bears provide valuable information about levels and effects of pollutants.

Photo: Heli Routti, Norwegian Polar Institute

species. Much ongoing research focuses on these currently used chemicals to document their persistence, capacity for long-range transport, and toxicity; such information is needed for regulatory processes.

Some arctic species such as polar bears are very efficient at metabolising pollutants in their body. Metabolism converts a pollutant to a more water-soluble form so that it can be excreted with the urine. However, these processes do not always lead to reduced concentrations of pollutants in the body, as some metabolites are retained. For example, polar bear blood contains much higher concentrations of PCB metabolites than of "parent" PCBs. To make matters worse, the metabolites are more toxic than their parent compounds. The chemical structure of some PCB metabolites resembles that of natural hormones, and they bind to the proteins that normally carry these hormones. Such mechanisms may thus lead to hormonal imbalance and impaired health of animals with high levels of pollutants.

CLIMATE CHANGE CAN MAKE ARCTIC PREDATORS ESPECIALLY VULNERABLE TO TOXIC EFFECTS OF POPS

Many arctic species vary considerably in body weight with the season due to variations in temperature and food availability, as well as energy expenditure during migration, reproduction and moulting. The use of fat reserves during these periods leads to re-mobilisation of lipid-soluble pollutants such as PCBs; the POPs then move from fat tissue to vital organs such as liver, blood and brain. We have recently shown in a study on arctic foxes that also concentrations of protein-bound compounds such as perfluorinated compounds are higher in lean compared to fat animals. This means that arctic predators may be more susceptible to the toxic effects of pollutants during seasonal emaciation periods.

High levels of pollutants are found in arctic foxes from Svalbard. This top predator and scavenger takes its food from both marine and terrestrial food webs.

Photo: Eva Fuglei, Norwegian Polar Institute

Polar bears are immobilised from helicopter prior to sampling.

Photo: Heli Routti, Norwegian Polar Institute

Increased susceptibility when energy expenditure exceeds energy intake is especially alarming because warming climate leads to increased energetic costs for several arctic species. The polar bear is among the species most vulnerable to climate change because it depends on sea ice when it hunts for ringed seals. Longer ice-free summer seasons and greater seasonal variation in sea ice extent are particularly demanding for pregnant or lactating females and may ultimately affect reproductive success and population growth. Increased tissue concentrations and re-mobilisation of POPs during these already tough periods exposes the bears to yet another stress factor, and a combination of multiple stressors has been proposed as a worst-case scenario for arctic wildlife.

Fasting is a stressful situation, which requires optimal control of energy metabolism to maintain an adequate supply of energy to all organs. Our ongoing research suggests that exposure to pollutants may affect processes that control how fat is stored and burned in polar bear tissues. These results, along with previous studies about the effects of pollutants on the thyroid hormone system, suggest that exposure to pollutants may have a detrimental effect on several physiological processes that are essential in helping polar bears adapt to rising temperatures and shrinking sea ice habitat. Pollution may therefore reduce the capacity of polar bears to adapt to environmental stress, such as climate change.

Tore Hattermann // Akvaplan-niva
Arild Sundfjord // Norwegian Polar Institute

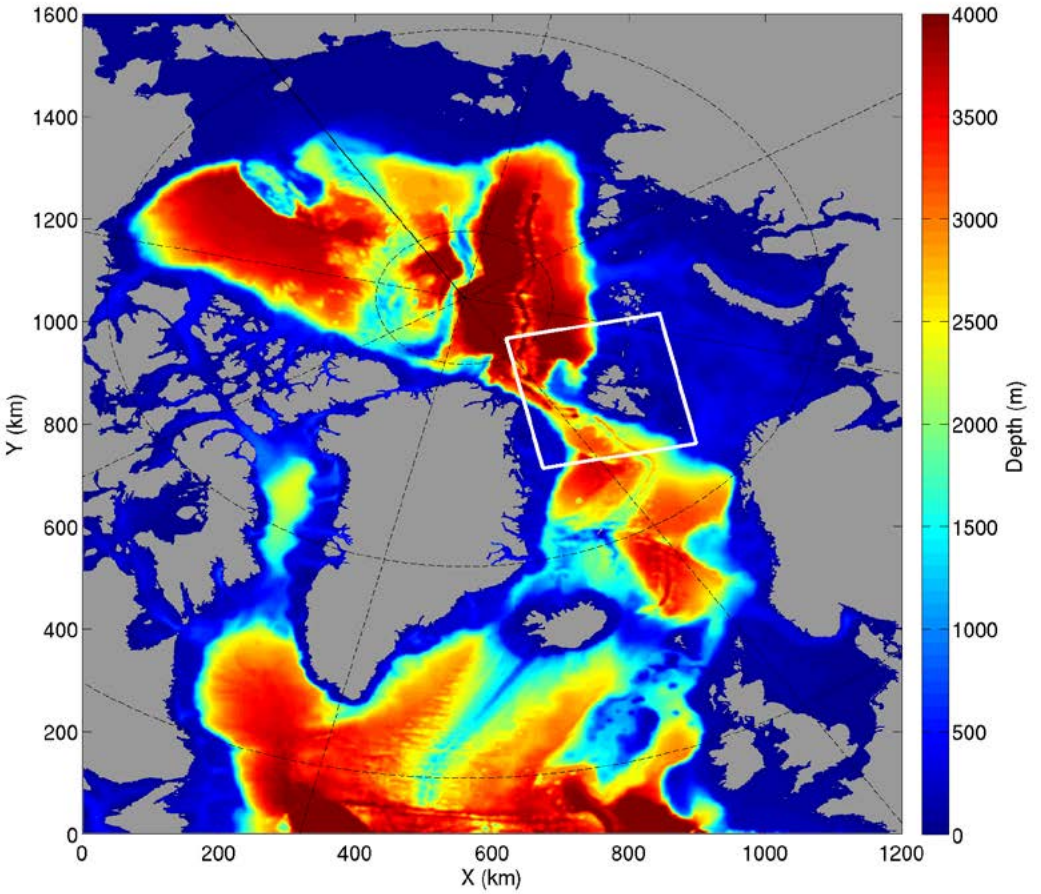
State-of-the-art tools for simulating sea ice, ocean and ecosystem dynamics in the Arctic Ocean

Within the Fram Centre's Arctic Ocean flagship, a large project is devoted to development of tools for simulation of the sea ice cover, ocean circulation and the lower-trophic-level ecosystem in the Arctic Ocean. A coupled numerical modelling system covering the entire Arctic Ocean and the surrounding shelf seas in high resolution has been established and is now being optimised and used for several purposes.

UNDERSTANDING AND PREDICTING the ongoing changes in Arctic Ocean sea ice cover is a major challenge when assessing the impacts of global climate change in the Arctic. This is in part because it is impossible to make continuous observations of the sea ice cover and underlying water masses in remote and logistically challenging areas like the Arctic Ocean. Although satellite-borne sensors are starting to provide good coverage of some sea ice parameters, the few existing observations of ocean state and ice thickness are either time series from a few selected points of interest, or snapshots from higher-resolution surveys covering very limited time periods.

Fortunately, the processes governing ocean circulation, sea ice growth and melt, the distribution of radiation, to mention but a few, broadly follow known laws of nature. These fundamental relationships can be represented by numerical algorithms in a model domain of time and space, and simulations can be made to understand more about the interplay of currents, sea ice and ecosystems. Once they are established, such models may serve as a tool for other purposes, like assessing the high-latitude oceanic uptake of CO_2 or spreading of pollutants, as well as for operational forecasting purposes for marine activities and for making climate scenario simulations.

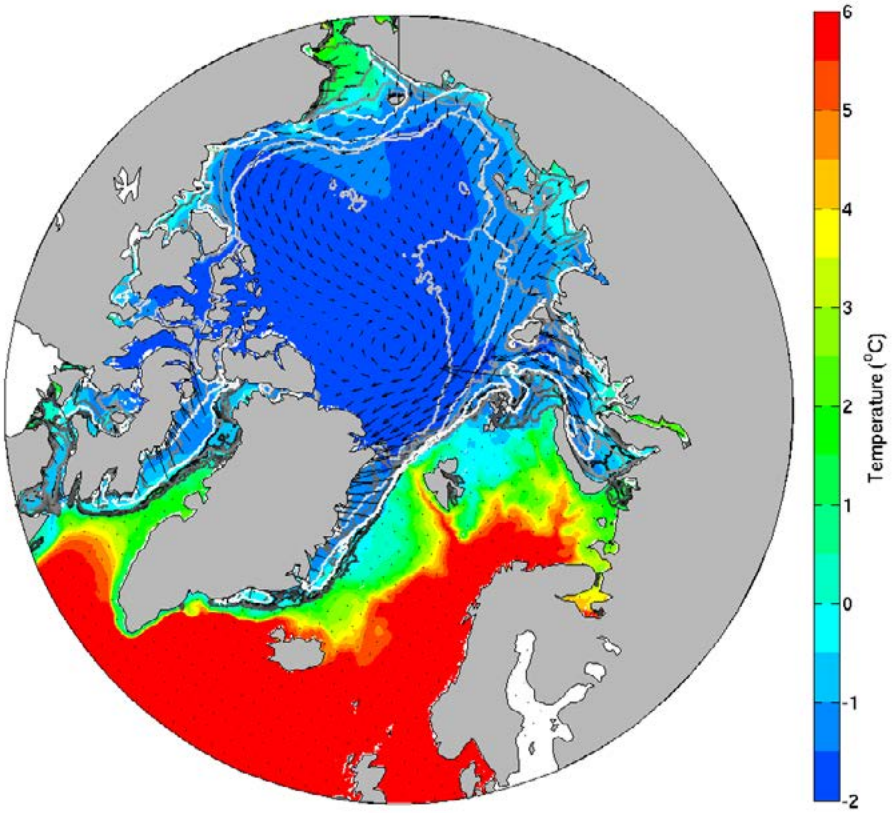
A key element of the new modelling tools being developed within the Arctic Ocean flagship is their ability to resolve the mesoscale dynamics of the ocean circulation. At high latitudes, the effect of the Earth's rotation on ocean circulation is profound. Thus, the closer to the poles, the finer the model resolution (horizontal distance between model grid points in space) must be to capture the so-called mesoscale eddies, which



This map shows the extent of the 4×4 km pan-Arctic sea ice, ocean and ecosystem model that is being developed within the Arctic Ocean Flagship (A4 model). Colours show bottom topography of the ocean component. The white box around Svalbard indicates the extent of the 800 m model that is nested into the A4 model.

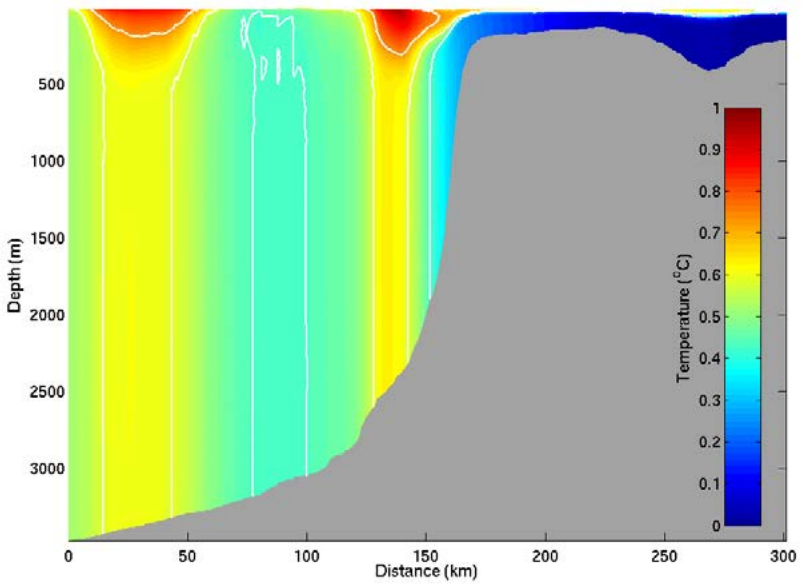
are assumed to play a key role in distributing kinetic energy, heat and salt in the ocean. Two different grids have been established, one covering the entire Arctic Ocean and the Nordic Seas at 4×4 km resolution, and one for the Svalbard area including Fram Strait at 800×800 m resolution (see map). The resolution of 4 km in the pan-Arctic model (known as the A4 model) allows us to study the role of mesoscale eddies on the large scale circulation, while the 800 m model also resolves smaller processes, such as the interaction of boundary currents with the coastal circulation around Svalbard.

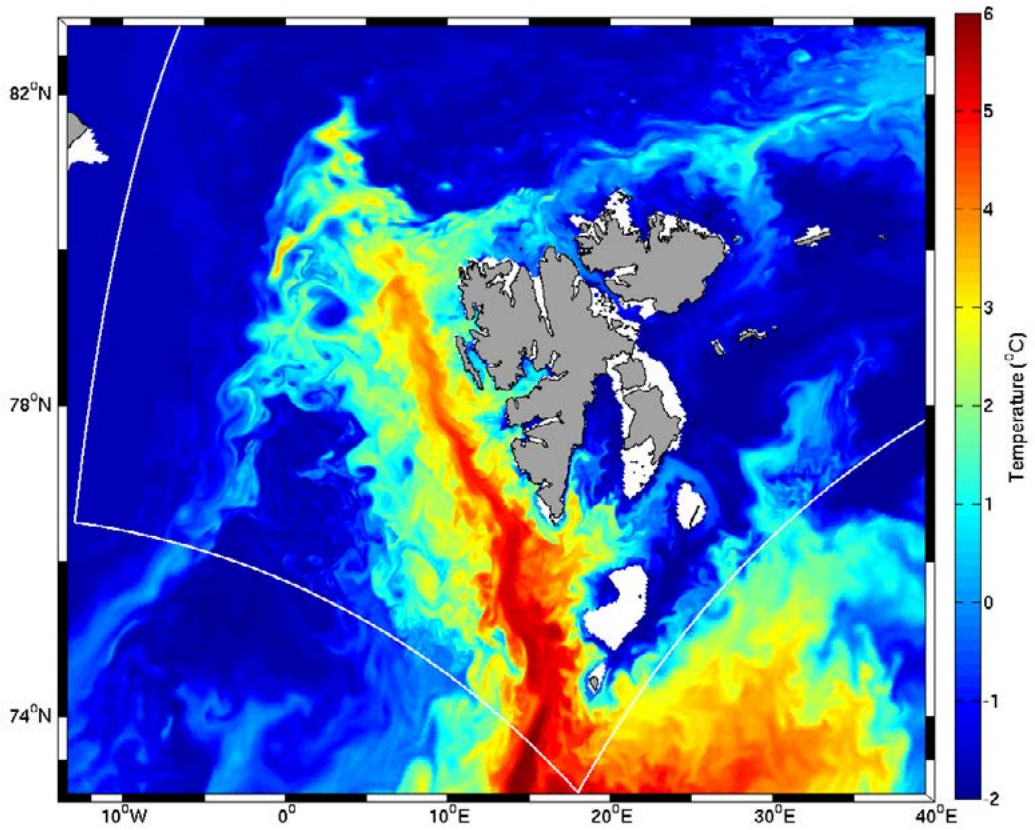
The core of the project is the freely available community model ROMS (Regional Ocean Modelling System). In the first phase of the project, a rather simplistic sea ice model that was embedded in the available version of ROMS was used. In 2014, a large part of the project



Example of climatological mean fields computed with the A4 model. Colours show the mean near-surface ocean temperature at 5 m depth for 2005 to 2010. The grey lines show the monthly averaged 90% sea ice concentration boundary within same period and indicate the seasonal variability of the sea ice extent in the model. Vectors show typical sea ice drift velocities in January.

Cross-shelf temperature transect from the A-TWAIN area at 30°E northeast of Svalbard. White velocity contours indicate the location of the slope currents, which carry warmer and more saline Atlantic Water into the interior Arctic Ocean.





Snapshot of simulated sub-surface ocean temperature at 50 m depth in the Svalbard and Fram Strait region. White curves indicate the transition from coarser A4 model results to high-resolution 800×800 m fields around Svalbard. Results from both models are shown as a composite in this figure.

work has been devoted to coupling the most recent state-of-the-art sea ice model, CICE 5.0, to the existing system. Another significant part of the project is to simulate the fundamental components in the arctic marine ecosystem. For this purpose, the well-established SINMOD lower-trophic-level ecosystem module has been adapted to interact with the ROMS.

Simulations were completed for the period 1993-2010 with the A4 model and for 2003-2010 with the 800 m model. Allowing for a sufficient spin-up time*, we compared the model results with actual observations made between 2005 and 2010. Those years were selected as the target period because a good volume of data is available after the extraordinary efforts of the International Polar Year (2007-2009). Work is ongoing to extend the simulations up to the present time to capture periods for which more data are coming in (for example from the Fram Centre A-TWAIN project), and to better understand notable interannual changes in the regional ocean-sea ice system that have been observed around Svalbard in the last few years.

*) The spin-up time is the period assumed necessary from the start of each model simulation until the results are independent from initial input conditions. In our high-resolution regional models, the input data we use come from coarser global simulations.

- The project called Mesoscale Modelling of Ice, Ocean and Ecology of the Arctic Ocean (ModOIE) is developing a common ocean–ice–ecosystem modelling system for the Arctic Ocean, to be shared between the Fram Centre partners.
- ModOIE uses the community model ROMS (Regional Ocean Modelling System, www.myroms.org) as a core tool for simulating the Arctic Ocean general circulation on NOTUR high-performance computing facilities at the Universities in Tromsø, Bergen and Trondheim.
- About 30 TB of model results were produced in 2014 and are now being analysed to study the Arctic Ocean circulation and improve the model for future simulations.
- Many Fram Centre partners are involved in the project. It is led by Akvaplan-niva, which has been responsible for setting up and running the 4 km model. MET Norway has been in charge of coupling the CICE sea ice model to ROMS. The Institute of Marine Research established and ran the 800 m model nested into the 4 km model. SINTEF is responsible for adapting their ecosystem model to the system. The Norwegian Polar Institute collected available observational data and contributes to the model analysis and evaluation.

Several publications are currently being prepared within the project. One manuscript presents work evaluating the role of mesoscale eddies in distributing energy along the continental slopes and fronts of the Arctic Ocean. Another paper will describe how the transport of heat into the Arctic Ocean is affected by different recirculation mechanisms in the Fram Strait. We are also comparing the simulated seasonality of mixed layer depth in the model with observations and other Arctic Ocean models. Associated projects will use results from ModOIE to describe the freshwater circulation around Svalbard as well as interaction between coast, fjords and glaciers. Last but not least, other initiatives have been taken to improve the model system, specifically targeting the ice-associated ecosystem and the distribution of radiation through sea ice and into the water column. Only our imagination and our budgets limit the possibilities for expansion and application of the new system!

NEWS

RESEARCH IN THE ICE

On 12 January 2015, the first weather balloon was sent up from the research vessel *Lance*, which is frozen into the Arctic Sea ice north of Svalbard. The balloon launch marked the first practical data collection within a major multidisciplinary research project under the auspices of the Norwegian Polar Institute. The primary objective of the Norwegian Young Sea Ice Cruise (N-ICE2015) is to obtain comprehensive new data that will enable future modelling of sea ice developments in the Arctic. The work can be followed live as long as RV *Lance* is in the ice (go to www.npolar.no/en/projects and search for N-ICE2015). The project was also presented in Fram Forum 2014.

Eirik Mikkelsen // Norut – Northern Research Institute
Jannike Falk-Andersson and Claire Armstrong // Norwegian College of Fishery Science, UiT The Arctic University of Norway
Isabel Seifert Dähnn // Norwegian Institute for Water Research

Ocean acidification…? What's it going to cost us?

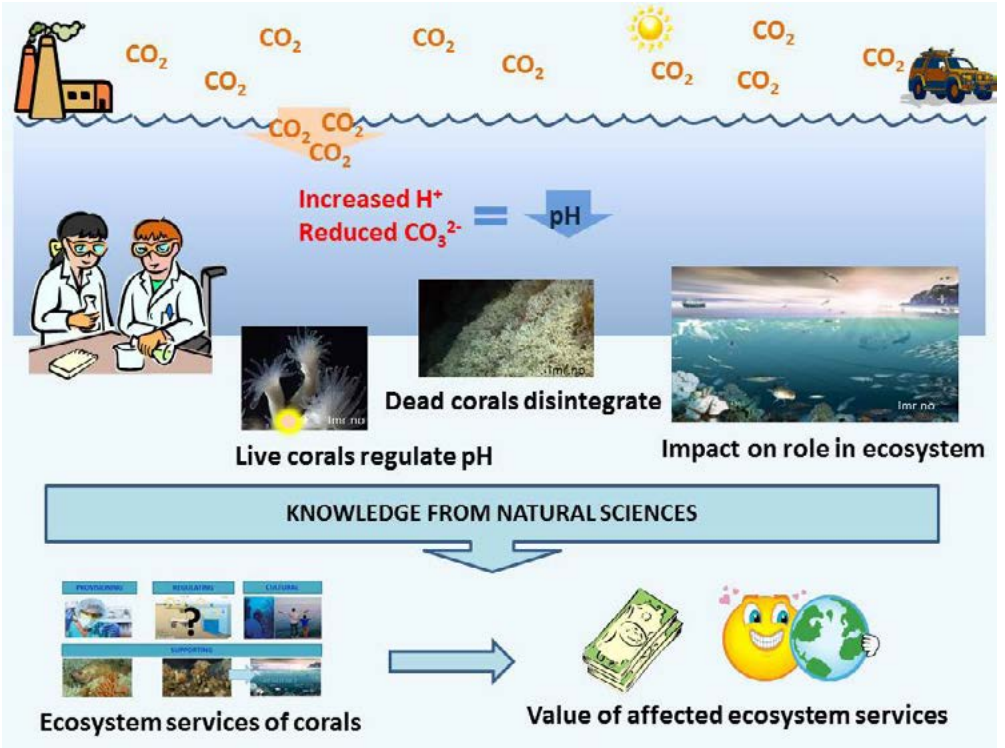
Human CO_2 emissions not only lead to climate change, but also make our oceans more acidic. Ocean acidification can affect organisms in the sea that we humans benefit from and appreciate. To make good decisions on actions to limit or deal with ocean acidification we need to understand, measure and publically discuss its effects.

THE COSTS OF OCEAN ACIDIFICATION are not as easily visible as prices in a grocery store. But they are important to know when considering measures to reduce ocean acidification or its effects. Estimating the costs of ocean acidification requires a series of steps involving oceanographers, chemists, ecologists and economists. Constructing a price tag is not easy, and the number we arrive at comes with uncertainties. But is a better guide for policies than no price tag at all, because it communicates that the costs are not zero. We have explored the economic impact of ocean acidification on the cold-water coral species *Lophelia pertusa*.

This coral lives deep in the sea and consists of colonies of small animals that produce an outer skeleton of calcium carbonate. Over the years these colonies grow into a coral reef, consisting of both dead and live corals. The world's largest known cold-water coral reef is the Røst reef, outside Lofoten in Norway. Both the dead and the live part of the coral can be affected by ocean acidification. Before going into any greater detail, we will introduce the idea of *ecosystem services* to explain how you may benefit from these creatures that you might not even have heard about. Cold-water corals provide *supporting ecosystem services* such as habitat for fish and other organisms. Also, since coral reefs sustain ecological communities with high biodiversity, they may provide a form of "insurance", making the ecosystem more capable of handling stress and disturbances.

Provisioning ecosystem services come from materials produced in the ecosystems, which we can use directly. Although some use corals for jewellery, the reef's main provisioning service is its potential for providing raw materials for industrial and pharmaceutical uses. Living at extreme depths and low sea temperatures, corals probably have unique biochemical properties that may be useful for us in the future.

Corals also provide *cultural ecosystem services*, such as aesthetics, knowledge and appreciation of organisms' and ecosystems' existence. Not many cold-water coral reefs can be visited by divers, but films and books have made their beauty known. When people



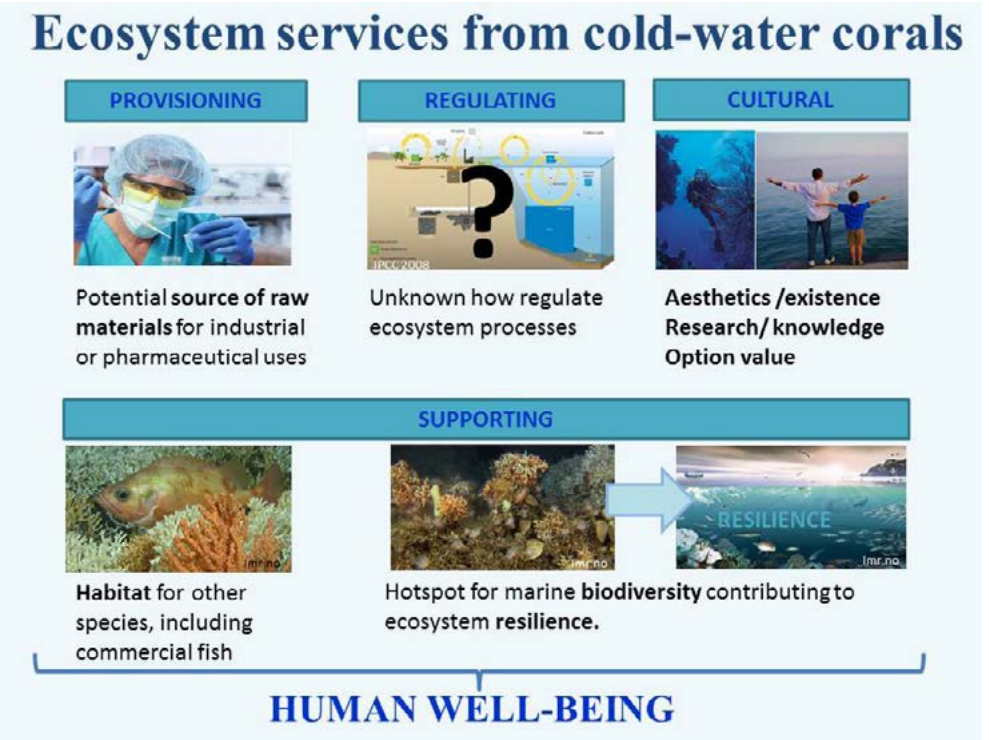
Understanding the effects of ocean acidification requires many steps and disciplines.

learn about them, most are fascinated and want them protected. In addition, old reefs function as archives that scientists can use to investigate past climate conditions.

The jury is still out regarding how cold-water corals might be affected by ocean acidification. Short-term experiments indicate that the live part of the coral may withstand increasing acidity, but in the long run this may tap into their energy reserve. On the other hand, live coral organisms may adapt to increased acidity over time. However, most of a reef consists of dead coral, which is susceptible to ocean acidification. The dead coral structures lift the live corals into conditions where they thrive, and also make up the majority of the habitat of a reef.

If ocean acidification is a threat to cold-water corals, what should we do about it? In politics, and in everyday life, we usually weigh the cost of doing something up against what we gain from doing it. To make the same sort of evaluation for corals, we can start by trying to estimate the value of the ecosystem services at risk - and present it in a currency that can be communicated to decision makers.

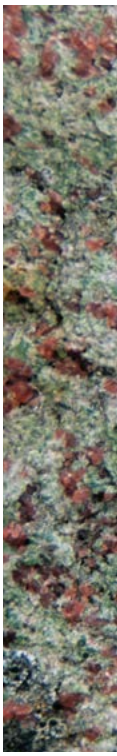
Cold-water corals in Norwegian waters were captured on video in 1982 when Statoil was looking for oil. Later, images of coral reefs destroyed by trawling made an impression on the general public, and soon after, several cold-water coral reefs were protected through area closures. This was done despite limited knowledge of what use cold-water corals might be to humans. These closures could reflect both that people valued the pure existence of corals, and that they wished to protect the yet unknown values the corals may represent. What people are willing to give up *today* to keep uncertain *future* options available is called "option-values", and is linked to the application of the precautionary principle in management.



Ecosystem services from cold-water corals contribute to human welfare in many ways.

Fishers believe that corals are important habitat and nursery areas for fish. Scientists have not been able to prove that corals are essential for specific fish stocks. Still, it has been estimated that for each square kilometre of coral reef that has been destroyed in Norwegian waters, up to 700 000 NOK in income may have been lost due to possible reductions in redfish harvest. Studies in Ireland and Norway have investigated how much people are willing to pay to protect cold-water corals, and why. The studies showed that people do indeed value protection of corals: people emphasise both that corals have a right to exist, independent of their utility for humans, and that they should be protected for the benefit of future generations.

The future effects of ocean acidification can be limited by reducing the emissions of CO_2 now. That requires cuts in the use of fossil energy, which will impact short-term material welfare in both industrialised and developing countries. How to compare costs or benefits that come long into the future with effects closer to the present is something economists still discuss. When deciding on policies we should have as good information as possible on the costs and benefits of doing it. However, not everything can be measured in monetary terms, and there will always be uncertainties. The *Lophelia* case study illustrates that while the price tag estimated is incomplete and uncertain, cold-water corals do represent important values to humans. Furthermore, it shows that ethical considerations and a precautionary approach have important roles in deciding on environmental protection policies.



Synnøve Elvevold // Norwegian Polar Institute

Eclogites – colourful rocks from the depth

Eclogite is my favorite rock. An eclogite can be striking in appearance with red to pink garnets set in a green matrix of pyroxene. In addition to having attractive colours, eclogites can sometimes even contain teeny tiny diamonds. What more can you want from a rock?

But the most important feature is that the occurrence of eclogite has a specific scientific meaning, because these rocks can only form at depths below the base of the Earth's crust.

JOURNEY TO THE DEEP DARK DEPTHS

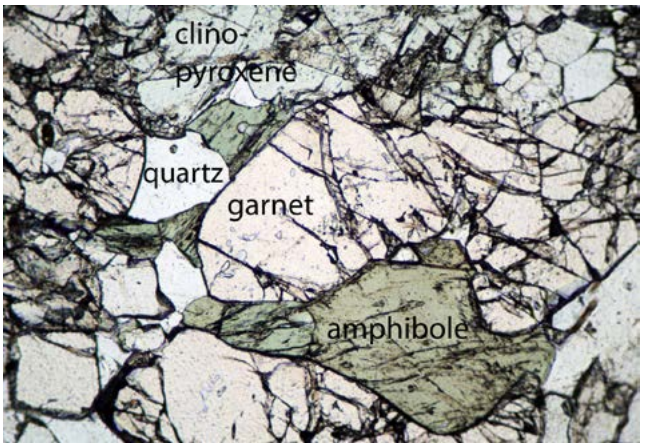
Eclogites begin their lives as mafic rocks (basalt and gabbro), which then descend deep into the Earth. Mafic rocks turn into eclogites 50 km or more below the surface. Imagine that! Crustal rocks reach to these depths within subduction zones, which are places where lithosphere plates collide. When crustal rocks sink into the depth, new minerals form; for example, a mundane, everyday mineral such as plagioclase is no longer stable and breaks down, forming sodium-rich pyroxene. At depth, the stable minerals are generally denser, heavier and harder. Because eclogites are very dense rocks, they are inclined to sink even deeper into Earth's mantle. Nevertheless, some eclogites may, against all odds, return to the surface where we can enjoy them.

THE TALE OF A ROCK

Rocks tell stories, and the minerals that make up the rocks are a type of chemical tape recorder that can be used to decode their journey within the Earth. Geologists refer to this journey as the rock's pressure-temperature-time path, or P-T-t path. Phase equilibria, geothermobarometry and thermodynamic modelling are methods used in constructing metamorphic P-T-t paths. Geothermobarometry relies on the fact that minerals vary their composition as a function of temperature and pressure, whereas thermodynamic modelling combines knowledge of the thermodynamic properties of minerals with analyses of the whole-rock composition and the mineral chemistry of the rock being studied. It is our goal as geologists to interpret the record left in the rocks in order to understand crustal-scale processes of mountain building and subduction.

Eclogites are colourful and eye-catching rocks – unless you are red-green colour blind. The main minerals of this sample are garnet (red) and pyroxene (green); in addition the sample contains small amounts of quartz and kyanite.

Photo: S. Elvevold

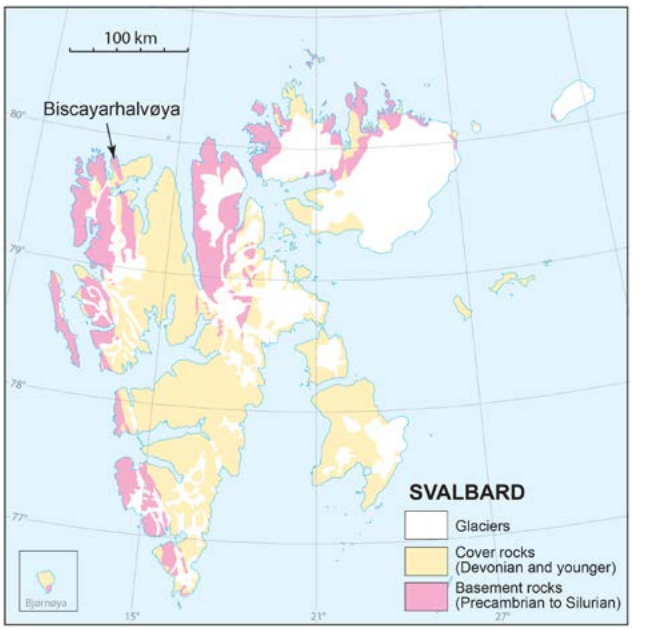


Microscope photo of eclogite from NW Spitsbergen (pink: garnet, light green: pyroxene, white: quartz, green: amphibole). The image is 2 mm across.

Photo: S. Elvevold

ECLOGITES FROM SVALBARD

Eclogite is globally an uncommon rock. Luckily for us, outcrops of these intriguing rocks are present in northwestern Spitsbergen at Biscayarhalvøya. Here, the eclogites sit on the surface, sandwiched between other - less exotic - metamorphic rocks. The metamorphic history of the eclogites has been unraveled through a combination of fieldwork, microscopy, chemical analyses, thermodynamic modelling and geothermobarometry. These eclogites formed during the Caledonian collision event about 450 million years ago. The P-T-t path demonstrates that they formed at pressures around 20-25 kbar and temperatures of about 725°C. Metamorphic pressures relate to depth of burial, and 25 kbar is equivalent to depths of 80 km! How does eclogite make it back to the surface? The answer is complex and not fully understood; however, uplift of the Svalbard eclogites involved a combination of erosion and tectonic exhumation.



Outcrops of eclogites are present in Biscayarhalvøya in the northwestern corner of Spitsbergen.

Jarle W. Bjerke and Hans Tømmervik // Norwegian Institute for Nature Research (NINA)

Less plant biomass of northern lands with increasing frequency of climate change-induced stress events?

Plant growth is increasing in some Arctic and sub-Arctic regions, a trend known as “the greening of the Arctic”. In other parts of the land area, growth is stable. But some parts show reduced productivity, a trend called “browning” – and browning seems to have increased during the last decade. This article describes insight gained from a stressful year in the Nordic Arctic Region.

Despite increasing temperatures during the growing season in most northern lands, only about a third of the area has had a significant increase in plant productivity. This has been documented using a satellite-based proxy for vegetation productivity, namely the normalised difference vegetation index, NDVI.

The Nordic Arctic Region, i.e. Norway, Sweden and Finland north of the Arctic Circle, is an example of a northern maritime region where productivity has been mostly stable during recent decades. The stable productivity of this region and other maritime regions stands in stark contrast to climate trends, which for most of the regions show a significant increase in summer and spring temperatures – which would be expected to promote growth of vegetation. Understanding the physical and biological processes leading to the decoupling of these two trends is considered one of the grand challenges for global change scientists and is crucial for making firm projections of the state of the Arctic in relation to both future carbon storage potentials and ecosystem resilience. Extreme climatic events are receiving increasing attention, and may play a significant role for this decoupling.

An opportunity to achieve new insight on this decoupling phenomenon came to us in 2012 when nature decided to play several tricks on the plant life in the Nordic Arctic Region. A recent publication in the journal *Environmental Research Letters*, written by us and colleagues, describes the many weather events and pest outbreaks from October 2011 to the summer of 2012 and how they affected vegetation productivity.

Vegetation greenness in 2012 was 6.8% lower than the 2000–2011 average, and an entire 58% lower in

Browning in a crowberry heath in Storfjord, Troms County.
Photo: Jarle W. Bjerke

the worst affected areas, which were under multiple stressors. Every season during the 2011–2012 hydrological cycle (starting in October 2011) included at least one extreme weather event. Autumn was unusually warm and this slowed down cold hardening in plants. The turn from autumn to winter was associated with the storm "Dagmar", one of the strongest storms Norway has seen in the last 30 years. Midwinter was extreme in the unusual combination of shallow snow depths and extreme fluctuations in temperature, from record low to unusually warm over short time periods, preceded and followed by numerous freeze-thaw cycles. The shallow snow depth led to exposure of many plants that under normal snow conditions would be covered by snow and thus sheltered from ambient temperature extremes and solar radiation (February–April). May to July was anomalously cool, delaying snowmelt and spring leafing. At summer solstice, the snow cover was more than double the norm. In mid-summer, some extreme minimum temperatures were measured related to five frost events. The lowest temperature recorded was –8.5°C in late June (extracted from MODIS LST satellite data). The summer also had periods of extreme rainfall causing flooding, and heavy storms causing salt spray on coastal vegetation. Snowfall and low temperatures in the high mountains during the entire growing season decreased the productivity there.

Furthermore, during the peak growing season, outbreaks of leaf-attacking insects caused major defoliation of trees and shrubs, and rust fungi caused premature autumn yellowing of willow trees.

All these events and outbreaks led to decreased plant vitality, as measured in the field, and reduced vegetation greenness, as measured by satellites. The various events affected different plant types. While evergreen plants like crowberry and juniper are most vulnerable to winter desiccation, frost events in summer mostly damage thin-leaved herbs and forbs. This effect was most striking in dense stands of tall ferns. Pest outbreaks mostly damage deciduous trees such as birch and various species of willow, but in the areas with the highest densities of moth caterpillars, forest floor vegetation also becomes defoliated. Re-surveys of sites with damaged evergreen plants in 2014 show that damage is still visible as non-vegetated areas with lots of dead, greyish plant remains.

The growing season of 2012 had the lowest mean summer temperature since 2000, and one could easily conclude that summer temperature constraints were the major factor for the observed decline in vegetation greenness. However, the fact that the greatest reductions in vegetation greenness in 2012 were found in areas exposed to one or multiple stresses, and that vegetation greenness is not significantly correlated with growing season temperature, clearly suggest that the events reported here have contributed strongly to the observed decline in vegetation greenness.

Because we reside at high northern latitudes and can arrange field campaigns at short notice, we were able to document the multiple anomalous weather and biogenic events causing plant stress to numerous vegetation types, thereby capturing an excellent example of a year with anomalously low plant productivity. Although our study area only makes up a small fraction of the land area north of the Arctic Circle, this study shows how multiple stressors may coincide and interact, and hence the results are valuable for highlighting the potentially large effects of partly understudied processes on arctic plant productivity. The projected increase in extreme events may cause a shift from stable to browning trends for maritime-buffered areas like the Nordic Arctic Region and other high northern areas. To our knowledge, there are no monitoring programmes that satisfactorily cover the types of events we have presented here, except for caterpillar outbreaks. We see an urgent need to incorporate such monitoring in ongoing Arctic monitoring programmes in order to better understand how factors other than average summer temperature, drought and wildfires affect plant productivity.

The results presented here were collected as part of the project EWWA (Extreme winter warming in the High North and its biological effects in the past, present and future) financed by the Research Council of Norway and the Fram Centre.

FURTHER READING:

Bjerke JW, Karlsen SR, Høgda KA, Malnes E, Jepsen JU, Lovibond S, Vikhamar-Schuler D, Tømmervik H. (2014) Record-low primary productivity and high plant damage in the Nordic Arctic Region in 2012 caused by multiple weather events and pest outbreaks. Environmental Research Letters 9(8):084006. doi: 10.1088/1748-9326/9/8/084006

NEWS

PHOTOGRAPHIC TREASURE TROVE SHOWS NATURE IS RECLAIMING THE LANDSCAPE

A unique series of historic aerial photographs of far northern areas of mainland Norway was published on the service website www.norgeibilder.no in December 2014. Research scientists from the Fram Centre combed the Norwegian Mapping Authority's archives and put together a collection of almost 400 photographs from the Varanger Peninsula from the years around 1970. The pictures provide a rare insight into landscape changes over the past four decades and are now being used to survey how the vegetation has changed in the areas of countryside bordering on the Arctic tundra.

More than 9 000 triangulation points, in a network ranging from the coast and all the way up to the high mountains on the Varanger Peninsula, were meticulously examined by researchers from the Fram Centre's flagship research programme on the effects of climate change on terrestrial ecosystems. The researchers, led by Jane Uhd Jepsen from the Norwegian Institute of Nature Research (NINA), discovered that about 20% of the surveyed area had changed significantly in the past four decades. Most changes were in the form of overgrowth and transformation either from treeless areas into thicket, or thicket into woodland. But the researchers also found signs of the opposite tendency.

"Large areas of woodland have been badly damaged by serious outbreaks of peppered moth infestation in the mid-2000s. In the short term, this destruction results in a more open type of woodland, which is clearly evident when we compare the area with the historic photographs," explains Jane Uhd Jepsen.

Justin P. Gwynn // Norwegian Radiation Protection Authority
Hilde Elise Heldal // Institute of Marine Research

Joint Norwegian–Russian expedition to investigate the sunken nuclear submarine K-159 in the Barents Sea

Of all the dumped and sunken objects containing nuclear waste in arctic waters, the sunken nuclear submarine K-159 in the Barents Sea represents the single largest potential source of radioactive contamination. This autumn, Norwegian and Russian scientists joined forces to assess the current status of the submarine.

THROUGH THE NORWEGIAN-RUSSIAN expert group for investigation of Radioactive Contamination in the Northern Areas, a joint Norwegian-Russian expedition to the Barents Sea was carried out in the autumn of 2014 to investigate the sunken nuclear submarine K-159. The purpose of the mission was to obtain up-to-date information about the physical condition of the wreck and investigate the levels of radioactive pollution in the surrounding marine environment. The last joint international expedition to the site of K-159 took place in 2007.

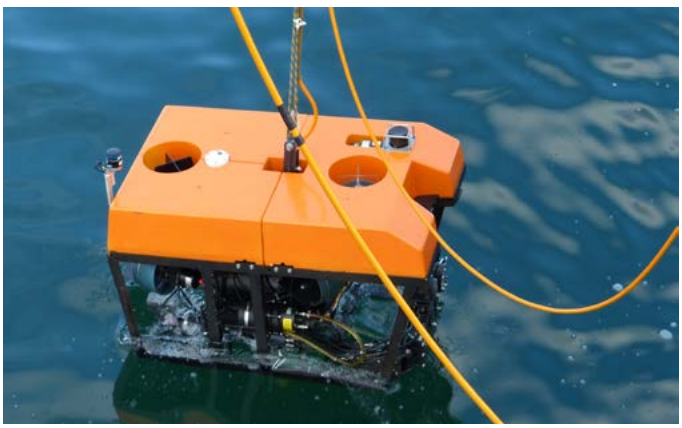
On the 30th of August 2003, the decommissioned nuclear submarine K-159 foundered and sank in heavy seas whilst under tow northwest of Kildin Island in the Barents Sea. K-159 was a November class attack submarine and belonged to the former Soviet Union's first generation of nuclear submarines. K-159 was being towed with the aid of flotation pontoons from a base in northwestern Russia to a shipyard for final dismantling. The loss of one or more of the flotation pontoons was determined to be the cause of the eventual sinking. Nine members of the towing crew were lost with the submarine.

K-159's two 70 MWt nuclear reactors had been shut down since 1989 but still contained around 800 kg of spent nuclear fuel. It has been estimated that the reactors on board K-159 contained a total radioactive inventory of some 7.4 PBq at the time of sinking. K-159 lies at a depth of 246 m in the Barents Sea in Russian territorial waters near important fishing grounds and at a distance of less than 130 km from the Norwegian border.

A previous modelling study by the Institute of Marine Research had showed that a pulse discharge of the entire Caesium-137 inventory from K-159 could result in increases of activity concentrations in muscle of cod in the eastern part of the Barents Sea up to 100 times

The author collecting water samples from around the sunken nuclear submarine K-159 for subsequent analysis of radionuclides.

Photo: NRPA

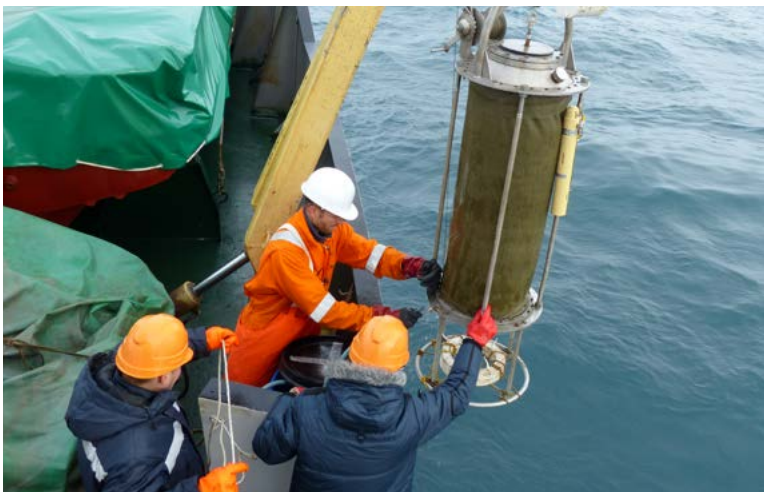


Deployment of the ROV used to investigate the status of the sunken nuclear submarine K-159.

Photo: NRPA

The Norwegian participants on the expedition (left to right) Hans Christian Teien (Norwegian University of Life Sciences–Centre for Environmental Radioactivity), Hilde Elise Heldal (Institute of Marine Research) and Justin Gwynn (Norwegian Radiation Protection Authority).

Photo NRPA



Norwegian and Russian scientists collecting bottom water samples from around the sunken nuclear submarine K-159. *Photo: NRPA*

Underwater photo of the conning tower of the sunken nuclear submarine K159. *Photo: NRPA*

current levels for approximately two years after the discharge. However, even in such a scenario the resulting activity concentrations in fish would likely be below national guidelines. Despite this, any radioactive leakage from the reactors of K-159 may have important economic consequences for Norwegian and Russian fisheries in the northern areas due to the general public's heightened sense of concern with regard to radioactive pollution.

The expedition lasted for three weeks and was carried out on the Russian research vessel *Ivan Petrov*. From Norway, there were participants from the Norwegian Radiation Protection Authority, the Institute of Marine Research and the University of Life Sciences. From Russia, there were participants from the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), the Kurchatov Institute and the Yuzhmorgeologiya research centre. The International Atomic Energy Agency (IAEA) was also represented on the expedition.

The expedition carried out video surveillance of K-159 with a remotely operated submersible (ROV) and conducted in situ radiation measurements at critical locations around the submarine such as above the reactor compartment. The ROV recovered sediment samples close to the bow, stern and on either side of the reactor compartment. Seawater, sediment and biota were also collected in the area around K-159; these will be analysed to determine the exact radiological status of the marine environment.

Video pictures showed that K-159 is lying upright on the seabed with the deck of the submarine covered in a layer of sediment. Several different fish species and other biota were observed around the submarine. The inspection of the outer hull showed a number of missing hatches and some damage to the deck and stern. The measurements conducted during the expedition showed that radiation levels around K-159 were low and typical for the Barents Sea. A similar picture for the radiological situation around K-159 was observed in 2007. Based on the results obtained so far, the conclusion of the Norwegian-Russian expedition is that no leakage has occurred from the reactors of the submarine to the marine environment.

"It's reassuring that the preliminary results show that there has been no leakage from this submarine. It will now be important to study the information collected from this expedition and discuss any plans for future action," said Per Strand, director of the Department for Nuclear Safety, Emergency Preparedness and Environmental Radioactivity at the Norwegian Radiation Protection Authority.

Russia and Norway will now cooperate on further detailed laboratory analyses of the collected samples and on drawing conclusions from this additional work. A final report based on the findings of the 2014 joint Norwegian-Russian expedition will be published by the end of 2015.

NEWS

NEW RESEARCH CENTRE IN TROMSØ

A new commercially oriented research centre is being established in Tromsø. It has been named the Centre for Integrated Remote Sensing and Forecasting for Arctic Operations and is one of 17 new Centres for Research-Based Innovation that received funding from the Research Council of Norway in November 2014. The Centre will be headed by Professor Torbjørn Eltoft of the Department of Physics and Technology at UiT The Arctic University of Norway.

As the host institution, UiT will collaborate closely with the Centre's research partners Norut, the Meteorological Institute, the Norwegian Polar Institute, the Norwegian University of Science and Technology (NTNU), and the Nansen Environmental and Remote Sensing Center.

The commercial partners of the new Centre are Kongsberg Satellite Services AS, Kongsberg Spacetec AS, Globesar AS, Aranica AS, Maritime Robotics, Statoil, Shell Technology Norway AS, ENI Norge, Aker Solutions ASA and Multiconsult. They include large businesses that conduct active research as well as small, recently established businesses that originate from the research environments in Tromsø.
The Research Council of Norway has allocated approximately NOK 1.6 billion over the next eight years to these new research centres, where new knowledge will be generated in close cooperation between businesses and research environments. The funding will trigger research worth more than NOK 3 billion over the next eight years.

NEW ARCTIC CENTRE FOR UNMANNED AIRCRAFT SYSTEMS

The Arctic Centre for Unmanned Aircraft Systems (ASUF) was launched in Tromsø in January 2015. It is a partnership between the Northern Research Institute (Norut), UiT The Arctic University of Norway, and the aviation company Lufttransport AS.

"We will be a national and international focal point in the use of unmanned aircraft systems for emergency response and environmental monitoring in the Arctic," says Rune Storvold, the Director of the new centre.

"Not least, this venture is about developing new and improved technologies and methods for remote sensing and climate and environmental monitoring. ASUF will collaborate with commercial partners and lead the development of new business activities and the civil drone industry in Norway," says the CEO of Norut, Ivan C. Burkow.

COOPERATION AGREEMENT WITH INDIA

Norway and India have signed a cooperation agreement to conduct polar research in the Arctic and Antarctic. India's keen interest in polar research and in cooperation with Norway is demonstrated by their research stations in Ny-Ålesund in Svalbard and in the Antarctic. Particularly important research themes for India are Antarctic climate processes and possible new trade routes through the Arctic. The parties met in October in the Fram Museum in Oslo to cement the polar cooperation between India and Norway.

Pål Christensen and Gunnar Grytås // UiT The Arctic University of Norway

The sea, fish and oil: 1970–2014

Towards the end of the 1960s, disaster loomed on the horizon. Herring catches had virtually ceased, down from over a million tonnes in the peak years of 1954 and 1956. The Atlanto-Scandian herring stock, as it was known, was on the verge of breakdown.

THE YEARS THAT FOLLOWED were a decisive turning point in the history of the Norwegian fisheries: an extremely serious depletion of resources led to a breakthrough for intervention by authorities and the imposition of regulations on the Norwegian fishing industry. Herring stocks were rescued at the last minute and slowly recovered with the help of tough restrictions on what had previously been relatively free fisheries. A totally new regulatory regime was gradually developed and expanded to include more and more fish species. Access to the fisheries was limited by a system of concessions and quotas. The effect on the fishermen, the fishing industry and the coastal communities was dramatic. These regulatory changes, though frequently contentious, were gradually accepted as necessary.

The 1970s were also marked by two very important political processes that both had to do with the relationship of Norway and the Norwegian fishing industry to the outside world. The first concerned the issue of membership in the European Common Market, which was determined in Norway by popular referendum in September 1972. The second concerned the development in Norwegian and international law of the sea towards the establishment of the Norwegian Exclusive Economic Zone of 200 nautical miles, which took effect on 1 January 1977. Both the debates surrounding these issues per se, and their outcomes, had fundamental importance for Norwegian society in general and for the country's fishing industry and coastal communities. Where the European referendum was concerned, the need to retain national control of fish resources was decisive in securing a majority vote against Norwegian membership. In terms of the law of the sea, the establishment of Norway's Exclusive Economic Zone came as a result of protracted discussions during parts of the Third United Nations Convention on the Law of the Sea (1973-1982), and internal Norwegian processes and negotiations with other coastal states, first and foremost the USSR and the EEC. An important point here is to examine what significance the boundrification of the sea with the establishment of the 200 nautical mile zone had for the possibilities of managing the fish resources sustainably.

The third factor that has made 1970 a natural watershed in the history of the Norwegian fisheries and coastal culture, is the start-up of the Norwegian petroleum industry, with the finds of the first exploitable oil and gas resources in the Norwegian sector of the North Sea being made in the Ekofisk field in 1969. Norway was on the threshold of an industrial and economic adventure. How this went on to transform Norway's fisheries and coastal communities is an important question.

Norway also saw the advent of a completely new kind of coastal industry in around 1970. Fish farming took the leap from freshwater ponds to sea cages and from small-scale production of rainbow trout to a large-scale salmon farming industry. In the 1980s, the industry was largely driven by regional policy objec-

tives, but this did not prevent overproduction and environmental problems. Policy later changed in a way that weakened the industry's local ties to the regions, leading to mergers and creation of large corporations – and far more industrial and efficient production methods. Several of the listed companies that arose at that time also have fish farming activities in Chile, North America, Scotland and the Faroe Islands. These developments have given Norway a completely dominant role in world production of Atlantic salmon, with 1.2 million out of a total of 2.0 million tonnes. Salmon exports make up over 60% of Norway's total seafood exports.

In the same way as the resource crisis in the herring fisheries at the beginning of the 1970s marked the end of an era, the crisis in the cod fisheries some 20 years later also led to dramatic changes in fishery policies. In 1990 the coastal fisheries were closed. Vessel quotas were introduced, with rules for allocating scant fish resources among groups of fishermen. The strong corporate system of control had seen its best days when the politicians determined to make the industry more subject to market forces. Fishery policy was judicialised and a Norway still sceptical of the EU became a member of the EEA. Overall, this triggered a major restructuring of the fishing industry, with liberalisation of the central regulations, the end of state aid, and new possibilities for imports of foreign raw materials. The entry of Kjell Inge Røkke into the Norwegian fishing industry augured a new era. The closure of the coastal fisheries in 1990 had major consequences in areas where local Sea Sami fishermen operated, where very few fishermen were part of the attractive individual vessel quota system. The question of Sami fishing rights was thoroughly investigated and placed on the political agenda, but without any recognition of special ethnic rights. This debate concerning power, rights and legitimacy also characterised the disputes within the fishermen's organisations over quotas, allocation of fishing rights, coastal fleets versus offshore fishing fleets, and disputes between the regions. The sealing and whaling industries have survived, despite international opposition. Yet the export markets both were dependent upon have been reduced to almost nothing.

While Norway had 43 000 commercial fishermen in 1970, there were only 13 000 in 2010. Yet overall, the country's population has grown substantially. This growth is weakest northwards along the coast, where the fisheries have been the cornerstone of local settlement. Some local municipalities and regions have also seen a fall in population, and are seeking new industries. Fishing tourism is one example of how the resources can be used in a new way. The relationship between fisheries, coastal culture and tourism has also sparked new interest in the use of fish for food. Fish has been marketed more intensively on the domestic market, and has gradually gained a more important place as a gastronomic experience in Norwegian restaurants.

With new principles of ecosystem-based fishery management and a series of international fishery management agreements, it is no longer the fishermen, but the fish, that are to be protected. Environmental and ethical issues have a more prominent place in fishery management. The consequences of climate change will also bring new challenges to coastal areas. Many threads must be gathered together when seeking to analyse Norway as a fisheries nation in an international context. Even though the Norwegian model of resource management has had considerable success in securing sustainable stocks, many important values issues remain.

The Norwegian fishing industry and coastal communities have undergone dramatic changes over the past 50 years. The number of people employed on the fishing boats and in the fishing industry has been greatly reduced. Both in the fisheries and on land, much of the labour has been replaced by capital in the form of machinery and high-tech tackle and equipment. State subsidies have been cut to a minimum, but the industry has nevertheless flourished. The sealing and whaling industries are technologically and economically among the most efficient in the world, and are largely operated in a regulated and sustainable manner. In contrast, although the fishing industry has gone through a process of enormous technological change, it is struggling with major problems of profitability and sharp competition from low-cost countries. The oil industry has left its mark on many coastal districts and represents a huge source of competition to the fisheries, both as regards the use of the sea, the threat of damage to the marine environment, and the competition to attract the best and brightest employees.

Many small communities along the coast of Norway are no longer inhabited year-round. *Photo: Kim Holmén*

The Norwegian coast has experienced a transport revolution without parallel. But in many places, the permanent residents have relinquished their houses and homes to holidaymakers and tourists. The coastal culture is alive and well, and has in the past few decades won a more prominent place in the national consciousness of what it means to be Norwegian. Many different forces have been decisive in bringing about this dramatic process of transformation, which also raises some important questions. How can it be that the fisheries and coastal industries are contributing to ever greater value creation, while at the same time the number of people employed in these industries is lower than ever? And when coastal communities are increasingly being seen as places of national heritage and cathedrals to nature and culture, why are so many of them losing their year-round inhabitants?

This article is based on "Havet, fisken og oljen 1970-2014" ("The sea, fish and oil: 1970-2014"), which is Volume IV of Norges Fiskeri- og kysthistorie (The History of the Fisheries and Coastal Cultures of Norway). This five-volume work was published in August 2014 as the result of a major research project involving five universities and university colleges. A single-volume abridged version of the work in English is also scheduled to be published in 2015.

Volume IV was edited by professor Pål Christensen, and the other contributing authors are Bjørg Evjen, Bjørn-Petter Finstad, Gunnar Grytås, Petter Holm and Ketil Zachariassen.

Join us on an exciting journey through the decades when the transformation of coastal life in Norway was more visible than at any time in the past.

Gudmund Løvø // Geological Survey of Norway

Compiling mineral data from around the Arctic

Key information about the most important metal and diamond deposits in the Arctic, north of the 60th parallel, is being collected to be made available on maps and in a database. The products will be ready for use in 2016.

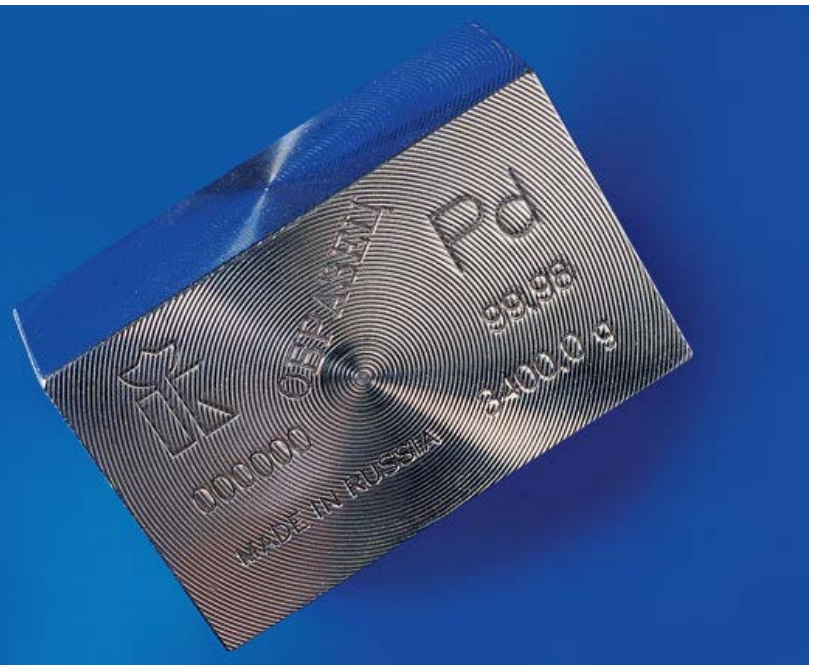
THIS MAJOR DATA COMPILATION PROJECT began in 2012 and is being coordinated by senior geologist Ron Boyd at the Geological Survey of Norway (NGU) in Trondheim. The background to the project is that the geological surveys in the Arctic have had a long-term cooperation resulting in a series of thematic products - aeromagnetic and gravimetric maps, bedrock geology and tectonics. General interest in mineral resources and in the Arctic made it natural to take up this topic. Norwegian authorities consistently point out that it is essential to have a knowledge- and research-based approach to the enormous land and sea areas involved.

"The Arctic contains large quantities of mineral resources," says geologist Ron Boyd, "which every indication shows will be gradually more thoroughly investigated and eventually exploited in the years ahead. For example, the EU is extremely interested in the supply of metals in neighbouring countries, and in gaining more knowledge about mineral raw materials that are and will be in critically short supply. If climate change persists and the ice continues to melt, the Arctic Ocean will become ever more accessible. We are already seeing an increase in commercial shipping in these waters. In 2013 more than 70 ships with a total tonnage of 1.4 million tonnes were registered sailing through the Northeast Passage between ports in Europe and Asia."

EIGHT COUNTRIES PARTICIPATING

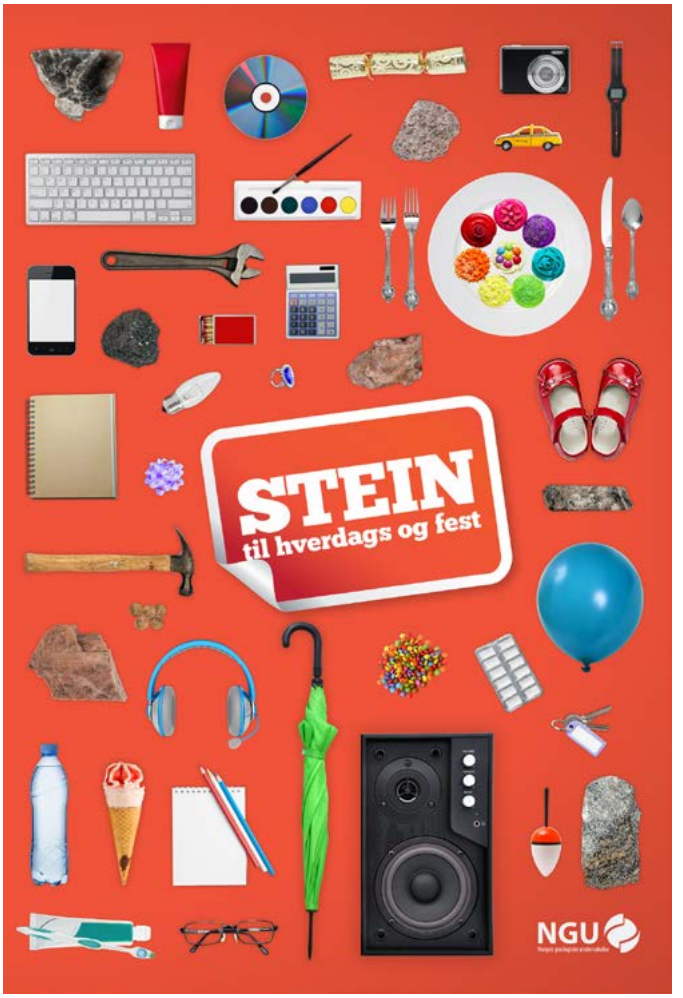
The geologists are now busy collating the knowledge that already exists in geological archives in all the countries bordering the Arctic. The work focuses on metallic ore deposits on land, on seabed mineralisation and on diamond deposits. Other industrial minerals are not included in the project, nor are coal, oil or gas.

"I'm glad that all the countries north of the 60th parallel have agreed to be part of this project," explains Boyd. "It means that we can get data from Alaska, Canada, Russia, Greenland, Iceland, Norway, Sweden and Finland. I believe this can be an excellent tool for industry,



A palladium bar produced at Norilsk Nickel mines in the Krasnoyarsk region of Russia.

Photo: Norilsk Nickel



Minerals are found in "all" the products we surround ourselves with: mobile phones, computers, machines, constructions, electrical wiring, electrical installations, wind turbines, cars, make-up, toothpaste, paint, ice cream, paper and batteries.

Illustration: NGU

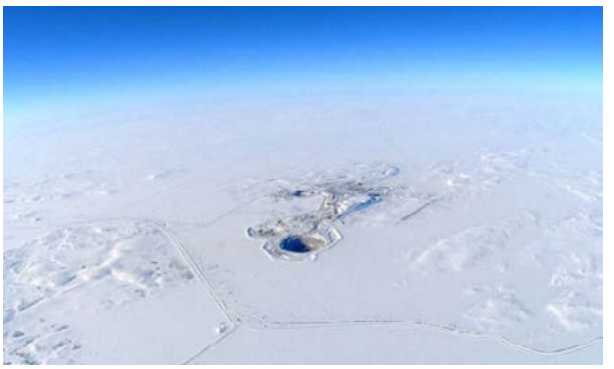
prospecting companies and researchers who are interested in the metal potential of the High North, but also for politicians and decision-makers."

The project is using the Fennoscandian Ore Deposits Database (FODD) as a model in the work to collate the deposit data from the Arctic. This database was developed earlier in cooperation with the state mineral agencies for northwest Russia and the geological surveys of Finland, Sweden and Norway.

HISTORY AND COOPERATION

This collection of knowledge of the mineral resources in the Arctic may be viewed as the fifth project of a similar type in the ongoing cooperation between the geological surveys in the northern areas.

In 2003, the Ministry of Natural Resources and the Environment of the Russian Federation (Rosnedra) took the initiative to bring about cooperation on a



Diavik diamond mine in Canada is the world's third most valuable diamond mine, and has an estimated lifetime of 16-22 years.

Photo: The Diavik Diamond Mine

THE FIRST MAPS

The world's first map of the North Pole is believed to be Mercator's Arctic projection from 1569, characterised by its depiction of what was thought to be a contiguous Arctic land mass. As early as 1599, Willem Barentsz, during an expedition to Svalbard, mapped parts of the far northern areas and what was then known as the Murman Sea and is now called the Barents Sea.

The work of collating the data to determine the size of the metal deposits in the Arctic is headed by senior geologist Ron Boyd at the Geological Survey of Norway.

Photo: Gudmund Løvø

First shipment of iron ore concentrate through the Northeast Passage from northern Norway to China in 2010.

Photo: Tschudi Shipping

new series of Circum-Arctic maps. The first product - a bedrock geology map at 1:5 million scale - was presented at the International Geological Congress in Norway in 2008. That work was led by J.C. Harrison of the Geological Survey of Canada. Two geophysical maps followed, in a project coordinated by senior geophysicist Carmen Gaina at the Geological Survey of Norway. The fourth product is an international tectonic map of the Arctic, also at 1:5 million scale, a project headed by director Oleg Petrov of the Russian geological survey VSEGEI.

"We are using a simplified version of the Circum-Arctic bedrock geology map as a base on which to plot the mineral deposits in the Arctic," says Ron Boyd.

SCOPE AND VALUATION

"We are systematising the deposits using the FODD classification into 'large', 'very large' and 'potentially large' deposits," Boyd explains. "It is important to have the correct basis for comparison when we do the classification. Amongst other things, we calculate the average price for the metals over a certain period and look at the value of the extractable resources." There is every indication that Norway will have some ten deposits put on the map.

In addition to preparing a Circum-Arctic mineral deposit map and database, the project will publish two books: one in English about the geology of the most important metal provinces and deposits, and a more general description, in several languages, aimed at decision-makers and interested members of the public.

"The Ministry of Foreign Affairs of Norway has shown great interest in the project. The Ministry is supporting the costs related to coordination, meetings and printing," says Ron Boyd.

SOME LARGE MINES

- One of the world's largest nickel-copper-platinum metal ore fields is in the Krasnoyarsk region of Russia. Norilsk Nickel is the world's leading producer of nickel and palladium. Norilsk also has the second largest platinum resources in the world and, globally, the tenth largest resource of copper. The company has been mining since 1939 and operates four mines in the region, as well as three washing plants and three metallurgical plants. Norilsk has 59 000 employees and known reserves sufficient to ensure operations for several decades to come.
- Diavik in the Northwest Territory of Canada is the world's third most valuable diamond mine, and has an estimated lifetime of 16-22 years. Mining has been going on here for eleven years, the last two years underground. The mine has approximately 800 employees, 67% of whom are from northern Canada. It is owned by the companies Rio Tinto and Harry Winston.
- The Red Dog lead and zinc mine in Alaska, run by the company Teck Resources, has 550 employees and is considered one of the world's largest zinc mines. It is estimated that the mine, which started up in 1989, is capable of maintaining operations until 2031, on the basis of known deposits.

NEWS

REINDEER CHANGING THE FACE OF FINNMARK

Large herds of reindeer are influencing the ecosystem in the coastal areas of Finnmark where they graze in summer.

"We are finding that the reindeer have a dramatic impact on trees and bushes. The impact on willow thickets is particularly marked. This again affects other species," explains Rolf Anker Ims, professor of ecology at UiT The Arctic University of Norway.

On the barren mountain plateaus of Finnmark, willow thickets provide an oasis for animals, where they can find insects and young willow shoots to eat.

Several species also use the dense vegetation for shelter and cover. The willow thickets are particularly important for the willow ptarmigan. In areas where the thickets have almost disappeared, ptarmigan populations have greatly declined.

Scientists have been studying the landscape by looking at aerial photographs and by conducting more detailed studies on the ground. They have surveyed and compared reindeer grazing districts with small and large herds.

"From aerial photographs we can easily register the spread of the mature thickets, which are up to two or three metres high. Out in the field, we have quantified small willow seedlings as well as the animal life," Professor Ims explains.

Where there are more than five reindeer per square kilometre, there are radically fewer of the small willow plants. Too many browsing reindeer prevent new willow plants from growing to maturity.

From the Norwegian Polar Institute Photo Archive.

Photo: Hanneke Luijting

Anne Katrine Normann and Eirik Mikkelsen // Norut – Northern Research Institute

Calling the shots. The insurance branch as an actor in developing the use of the Northern Sea Route

Shipping in the Arctic has a reputation of being a risky undertaking. Referring to the Northwest Passage, the Canadian Transport Minister Lisa Raitt commented in March 2014 that "*...insurance companies...are the ones really calling the shots about what ships would be allowed to pass through the area*". The same is valid for the Northern Sea Route, defined as the route from Novaya Zemlya to the Bering Strait. Insurance is a prerequisite for obtaining a transit permit from Russian authorities, and it is fair to say that the insurance branch strongly influences the development of traffic along the Northern Sea Route. Insurance representatives' perceptions and strategies of conditions for traffic development are thus of great importance. Here, we look at what insurance companies, along with ship owners, see as the risks of transiting the Northern Sea Route, and what role the insurance representatives have in reducing risks.

The transit traffic along the Northern Sea Route has seen a substantial relative increase the past years, albeit moderate in absolute terms, up from 4 vessels in 2010 to 71 in 2013, but then plummeting to about 31 in 2014. The amount of cargo in transit sailings dropped 77% from 2013 to 2014. The attraction of using this route is mainly savings in sailing distance and time, compared to sailing the Suez Canal. Russian authorities promote increased use of the route, and are therefore in the process of relaxing the requirements on shipping companies for sailing there.

The risks of navigating in polar waters are still not fully understood. Ice and fog make sailing in the Arctic risky. The potential consequences of colliding with ice must not be underestimated. With Russian authorities easing up on restrictions for sailing the Northern Sea Route, requests for sailing permits will be submitted by more shipping companies, some with limited experience of polar sailing. Insurance companies' knowledge of the Arctic will be an increasingly important source of information for ship owners seeking insurance. However, not all insurers are familiar with the sailing conditions in this part of the world. Those who are, are very concerned about safety measures. Ship owners need hull insurance, cargo insurance and protection and indemnity insurance (P&I). P&I insurance relates to third party liability, and hence to international laws and regulations, as well as national laws applicable to different nations' waters. If the ship has an accident, the ship owner may be liable for damages and clean-up costs of sea pollution, and for removing ship wreckage, and possibly also personnel injuries, for instance to the crew.

The major risk factors insurers see for ships sailing the Northern Sea Route are these:

- Unpredictable climatic conditions and sea ice.
- Poor mapping of the sailing routes and adjacent areas. Huge areas remain uncharted. One estimate is that only 15% of the areas relevant for sailing have been charted. Available charts are often seen as unreliable, and many are only available in Russian.
- Poor search and rescue (SAR) infrastructure. Russia is establishing ten new rescue centres, in accordance with the Arctic Council agreement on SAR cooperation. The first rescue centre was opened in Narjan-Mar in 2013. The other nine are due by 2015.
- Unreliable communication systems in arctic waters.
- Crew with little or no experience of polar sailing.

Estimating risks entails estimating consequences of possible incidents. Besides damage to the ship itself, other adverse consequences are loss of life, injuries, oil spills, chemical spills, and other damage related to third parties.

One factor in the unpredictability of the Arctic regards how accidents may be handled by the Russian authorities. Insurance representatives fear, for example, that this unpredictability might make dealing with oil spills more costly than necessary. Clean-up procedures depend upon the interpretation of national and international regulations and practices, including those that apply to the Northern Sea Route. There have been few serious ship accidents along the Northern Sea Route, which means that there are no obvious established routines for dealing with accidents in the area – at least not that insurance companies know about. In case of an accident there, the insurance companies may want to bring in their own salvage ships and equipment, operated by partners they have contracts with, and trust based on long experience. Whether this will be allowed or not is seen as a factor of uncertainty and unpredictability by the insurance companies.

Russian authorities are relaxing some of their requirements for sailing the Northern Sea Route, including when escort by icebreakers is required. Our informants all emphasised the necessity of ships using ice pilots and being assisted by icebreakers.

Requirements on the ice class of ships have also been eased for some areas, time periods and sailing conditions. This is contested by both insurers and ship owners, who find it unwise and risky. With no formal requirement for ice classification, traffic along the Northern Sea Route will increase – which of course is the intention. But so will the risk of accidents. As one ship owner commented: "*Actually, it is complete madness*!" In addition to the technical qualities of an ice class ship, an important point is that the crew of such a ship has experience from sailing in polar waters. Inadequate crew competence is a major risk factor.

Given that it takes time to construct the planned SAR centres, and suspecting that it might take longer than planned, availability of icebreaker assistance is more important at present. Insurers require their members to have icebreaker assistance along the Northern Sea Route, even though Russian authorities may allow otherwise. Shipowners equate icebreaker assistance with increased safety: "*An icebreaker carries everything you need*." In case of an accident, the first hours are critical. The proximity of an icebreaker may mean the difference between life and death. Icebreakers have towing services, workshops, medical personnel and crews with ample experience in Arctic waters.

There is concern about future scarcity of icebreakers. Analysis suggest that the available icebreaker fleet for the next five years will have problems handling even a small increase in traffic, let alone the official Russian traffic projections.

When it comes to the insurance branch's contribution to increasing safety, the insurance representatives with most Northern Sea Route experience are in frequent contact with Russian authorities, both in formal and informal settings. They find the Russian authorities informative and cooperative, but also evasive in some matters, which contributes to the sense of unpredictability. Nevertheless, through their interaction, the insurance industry is aware of its role as a promoter of safety precautions.

Eva Therese Jenssen // University Centre in Svalbard (UNIS)

Seeing in the dark: Cutting-edge Fram Centre research

TAKE ONE PART MARINE BIOLOGISTS and technology enthusiasts, take another part talented graduate students, and season with some high-tech underwater robotics and optical instruments. Place this well-equipped expertise in the northernmost settlement in the world in the pitch black darkness in early January and voilà! You have a pièce de résistance – an irresistible combination of cutting-edge engineering, marine science, education and the Arctic – recipe courtesy of the Fram Centre.

It all began in 2008 when scientists from several Norwegian and British institutions started investigating what was going on in the Arctic Ocean during the polar night. Until then, the assumption was that all organic life in the ocean went into hibernation in the dark season and that the Arctic Ocean was to all intents and purposes "dead". With the help of new technology, such as unmanned automated vehicles (AUVs) operating beneath the sea ice cover, the scientists were able to reveal that the winter ocean is not quiet, but actually is teeming with life.

The research took one step further in 2010, when scientists through a bilateral cooperation between Norwegian and American institutions went to the northernmost settlement in the world, Ny-Ålesund at 79°N, this time bringing new state-of-the-art optical equipment and PhD students to investigate further the mysteries of the polar night.

In 2012, the project continued with a Polar Night research cruise along the northwestern coast of Svalbard with students from the University of Tromsø and the University Centre in Svalbard (UNIS). And in 2014 the final step of this multinational research collaboration was taken: a full

Naked sea butterfly or sea angel (Clione limacina) photographed in Svalbard waters.

Photo: Geir Johnsen, NTNU/UNIS

Professor Geir Johnsen (NTNU and UNIS) teaching students about underwater robotics and polar night biology in Ny-Ålesund.

Photo: Jan Sivert Hauglid/UNIS

The marine lab in Ny-Ålesund in early January when there is still polar night at 79°N.

Photo: Jan Sivert Hauglid/UNIS

master/PhD course in underwater robotics and polar night biology was run in Ny-Ålesund in the first weeks of January.

The course is formally run by UNIS and attracts highly qualified students from all over the world. Together with Fram Centre partners such as UiT The Arctic University of Norway, the Norwegian Polar Institute, and Akvaplan-niva, the five week long course is really a symbol of true Fram Centre collaboration in the High Arctic.

RESEARCH IN THE TRUE FRAM CENTRE SPIRIT

"Our aim is to gather scientific expertise within several areas, including institutions that are world leading within the field of underwater robotics and couple them with institutions that are at the forefront in arctic marine studies, together with excellent students from all over the world," explains the leader of the field investigations in Ny-Ålesund, professor Jørgen Berge from UiT and UNIS.

"This is a prime example of cooperation in the Arctic in the spirit of the Fram Centre. UNIS, the Svalbard-based partner in the Fram Centre, is the nave of this cooperation with UiT The Arctic University of Norway, Akvaplan-niva, and the Norwegian Polar Institute," explains senior researcher Stig Falk-Petersen at Akvaplan-niva.

The university course is part of the project "Mare incognitum – ecological processes during the polar night" (Norwegian Research Council project number 226417/E10).

Together with other institutions, such as the Norwegian University of Science and Technology (NTNU), the University of Delaware (USA), the Scottish Association for Marine Sciences, the Alfred Wegener Institute (Germany) and institutions from Poland and Russia, the research group has produced new knowledge about the marine life in polar night. They found a "hoppin' party" down in the dark waters, where the marine organisms wander up and down in the water column to eat, produce eggs and pretty much go about business as usual.

However, the scientists also found new questions that need to be answered in the coming years. One of the most intriguing questions is: How do these organisms – many of whom dependent on eyesight to hunt for prey or avoid being eaten – know which way they should be heading? The researchers found that the marine organisms in the water are acutely sensitive to changes in light, such as moonlight and northern lights, even when humans perceive the darkness as "complete". But how are the sea creatures able to perceive changes in light in December and January, when the sun is more than 12 degrees below the horizon in the High Arctic and the sea surface may have an ice cover a metre thick to boot?

These questions remain to be answered, but this unique education–technology constellation will uncover more exciting knowledge about the life in the deep, dark Arctic Ocean, and simultaneously educate the Arctic experts of tomorrow.

http://www.mare-incognitum.no/

Christine F. Solbakken // NILU – Norwegian Institute for Air Research

Methane from sea to air?

In recent years, researchers have observed that the amount of methane in the atmosphere is increasing. Methane is a greenhouse gas that contributes to global warming. A change in natural methane emissions may cause the temperature to rise both more and faster than previously expected.

Methane is the second most important greenhouse gas in the atmosphere, and anthropogenic emissions arise mainly from agriculture (especially rice paddies and livestock), landfills and the petroleum industry. In addition, the gas is released from natural sources, such as termites, fires, wetlands - and the seabed.

FROM SEABED TO ATMOSPHERE

Senior scientist Cathrine Lund Myhre at NILU explains that scientists wonder whether emissions of methane from the seabed may be one source of the increased methane levels. Methane is stored under the seabed as methane hydrates - an ice-like substance - and scientists know that methane gas leaks from these deposits, forming bubbles that rise in plumes towards the surface.

Depending on the water depth, the bubbles may reach the ocean surface, or dissolve before the gas can enter the atmosphere. If the temperature of the sea rises, this may increase the methane discharge from the seabed to the sea, and thus contribute to a greater amount of methane reaching the atmosphere - with increased temperatures on Earth and in the ocean as a result.

MOCA: A RESEARCH COLLABORATION

To find out more about the relationship between methane hydrates on the ocean floor and methane levels in the atmosphere, the research project MOCA was initiated in 2013. The project is a collaboration between NILU, CAGE - Centre for Arctic Gas Hydrate, Environment and Climate at UiT The Arctic University of Norway, and CICERO, the Center for International Climate and Environmental Research.

The Zeppelin Observatory is located at 79°N on Zeppelin mountain, close to Ny-Ålesund, in the Svalbard archipelago. The observatory is located in an undisturbed arctic environment, far away from major pollution sources.

Photo: Ove Hermansen, NILU

The project will run for 3½ years, and during this time MOCA and CAGE, a world leading scientific community on gas hydrate research, will combine and coordinate measurements from ships, aircraft and the seabed, as well as from the Zeppelin Observatory in Svalbard. The main purpose is to determine how much of the methane emitted from the ocean floor reaches up through the ocean and into the atmosphere. In addition, the results will be used to quantify the effects methane from gas hydrates in the seabed has on the atmosphere today, and what a potential change in these release processes may mean for the climate in the future.

SCIENTIFIC EXPEDITIONS TO POLAR REGIONS

The measurements started in the summer of 2014, and in mid-June the UiT research vessel *Helmer Hanssen* left Tromsø for a six-week research cruise, aiming to measure parameters in the ocean and atmosphere between Tromsø and the waters off northern Svalbard. In the same region, CAGE will soon place monitoring equipment on the seabed, to measure ocean currents, temperature and methane bubbling and emissions. In addition to this, the project conducted two different flight campaigns, to measure the methane concentration and variation in the atmosphere. The first flight took place in June 2014, from Kiruna in Sweden to Longyearbyen in Svalbard, then north of Svalbard and above wetlands in Sweden and Finland. This was done in collaboration with the University of Cambridge. The second flight campaign, in collaboration with the French and Russian project partners, took place in the middle of October. This campaign ran from Novosibirsk, over Siberia and the wetlands there, and up to the area of the Kara Sea and Salekhard.

The FAAM research aircraft BAe 146 in the air over Prins Karls Forland on the west coast of Svalbard.

Photo: CAGE

Part of Isfjorden and Erdmannflya west of Longyearbyen as seen from the FAAM research aircraft BAe 146. Also visible on the wing is the measuring equipment used to collect air samples.

Photo: Ignacio Pisso, NILU

COMPARING OBSERVATIONS

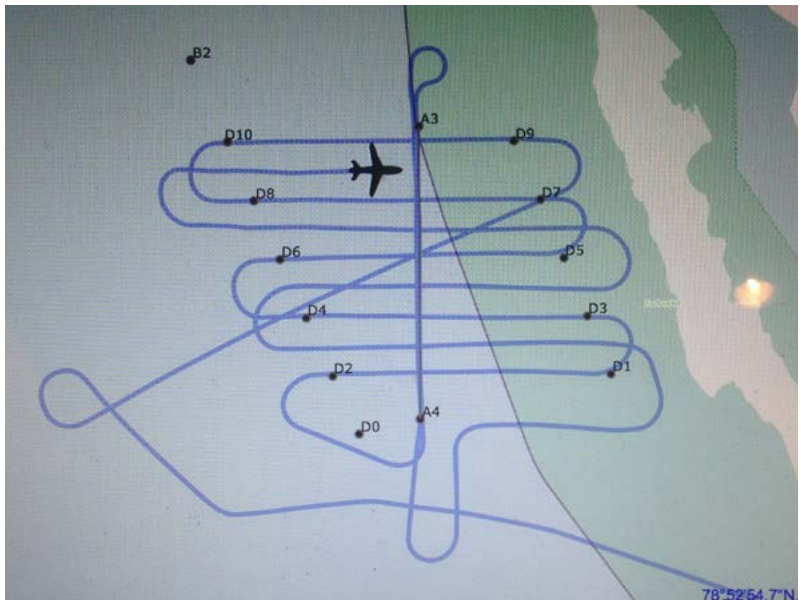
In the fall of 2014, the project partners gathered to compare observations. Project leader Cathrine Lund Myhre from NILU says the group is very satisfied with the summer activities; all the instruments worked mainly as expected on RV *Helmer Hanssen*, at the Zeppelin Observatory and during the flights. The procedures worked well, and the meteorological situation during the period was advantageous. One flight was even able to measure down to 15 m above the sea.

Atmospheric measurements are always influenced by transport episodes, seasonal trends, and local sources. Modelling work to analyse the transport and influence of air from polluted regions at lower latitudes is currently ongoing. So far, it looks very promising, and a comprehensive and robust data set will soon be ready for interpretation and discussion.

The RV *Helmer Hanssen* from UiT undertook marine and atmospheric measurements in the waters between Tromsø and the northern part of Svalbard.

Photo: Wikimedia Commons

RV *Helmer Hanssen* seen from the FAAM research aircraft BAe 146.
Photo: Ignacio Pisso, NILU



Screen capture of the onboard position system of the FAAM research aircraft BAe 146 during low altitude flight west of Svalbard. The ambitious raster flight track pattern initially planned included the points marked "D" in the figure. The mid-size aircraft flew consistently at about 100 feet from the surface, reaching 50 feet when doing profiles. The skilled pilots used reserve fuel to repeat the passages over the methane seepage area, doubling the amount of information collected. These measurements will be used with the results provided by the ship to assess the methane sea surface fluxes in the Arctic.

Photo: Ignacio Pisso, NILU

ABOUT MOCA

The MOCA project is interdisciplinary, combining research groups that have not previously collaborated, to promote better understanding of Arctic processes. The Research Council of Norway funds MOCA via the Polar Programme, and the project will last 3½ years from 1 October 2013.

In addition to NILU, UiT, and CICERO, MOCA also involves partners from Canada, France, Switzerland, Great Britain and Russia.

Read more about the MOCA project at
http://moca.nilu.no/

Jan H. Sundet // Institute of Marine Research

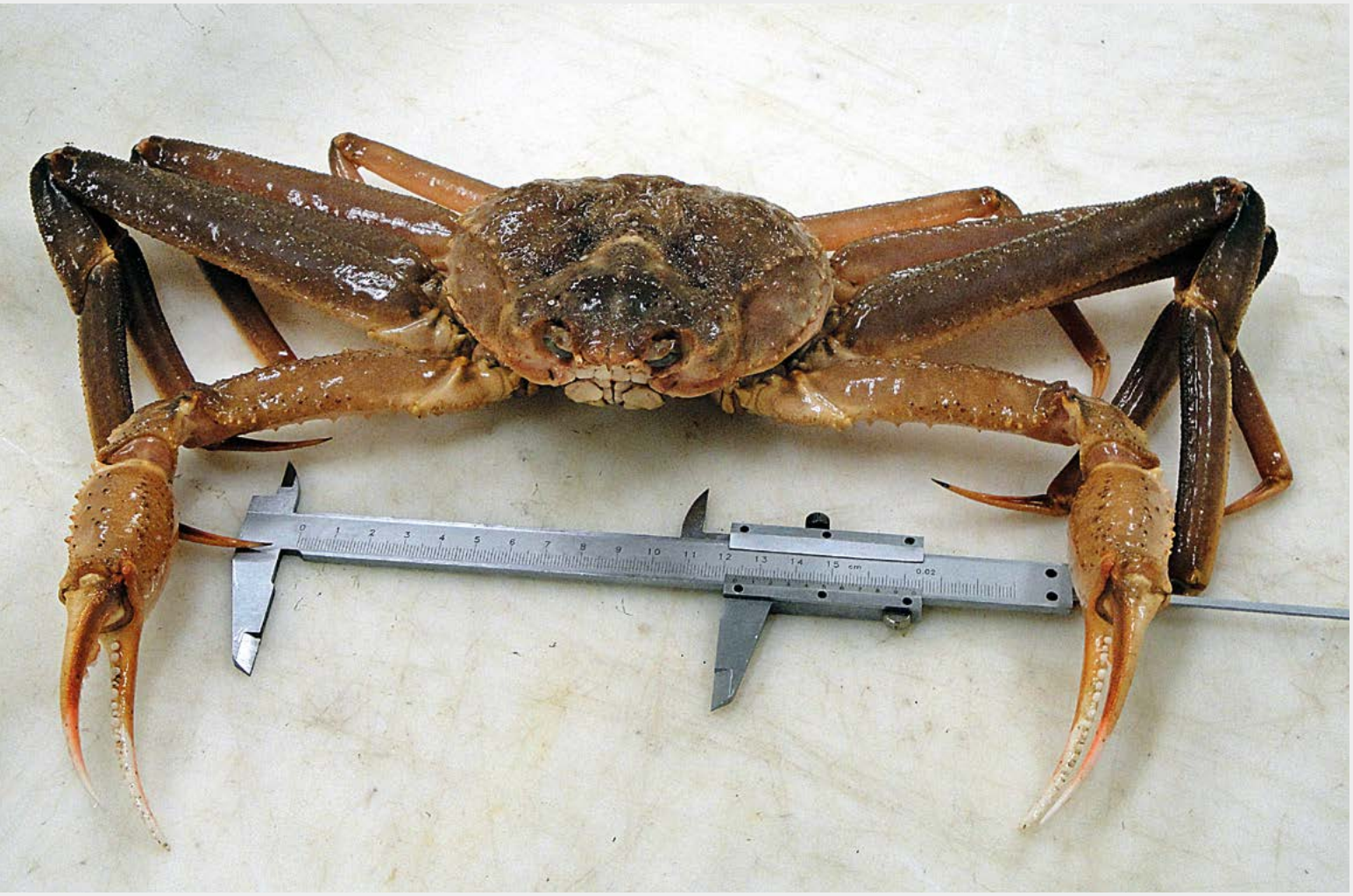
The snow crab – a new and important player in the Barents Sea ecosystem

In 1996, Russian researchers found five specimens of snow crab in the net of a trawler fishing for cold water prawn on Gåsbanken west of Novaya Zemlya. That was the first time this non-native crab species had been found in the northeast Atlantic. Nearly two decades later, there is still no credible explanation for how it arrived in the Barents Sea.

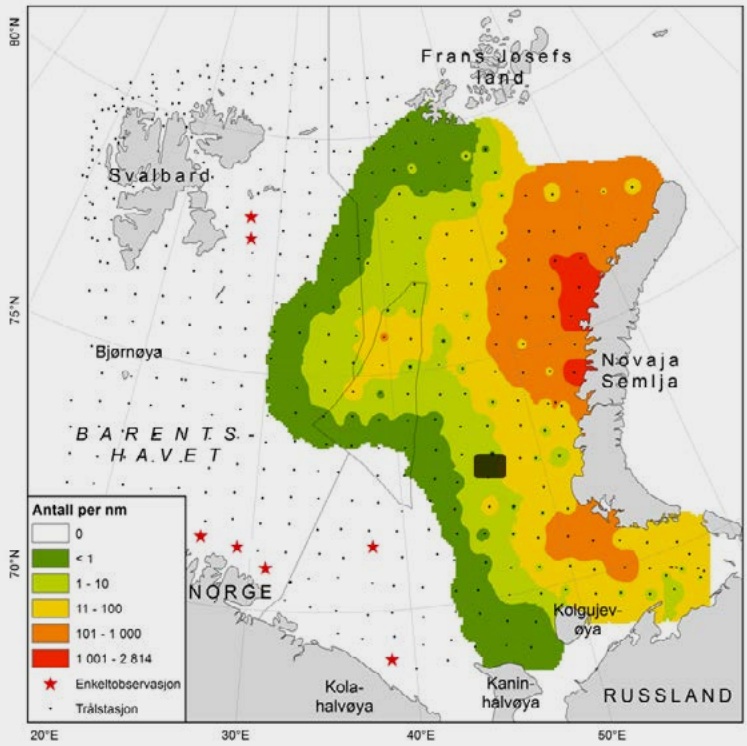
ONCE THE SNOW CRAB got to the Barents Sea, it had found an area where it could flourish, and in the years since 1996 the population has grown almost exponentially in terms of both numbers and distribution. While the snow crab's main habitat today is the northerly parts of the Russian Exclusive Economic Zone and in international waters of the Barents Sea (in the Loophole, or "Smutthullet" in Norwegian), it is also working its way into the Fisheries Protection Zone around Svalbard (see map). The exponential growth in snow crab numbers in the Barents Sea is a classic example of how a non-native, introduced species can grow and thrive in a new environment. Russian researchers at the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) in Murmansk have estimated that in 2014, in the Russian zone alone, there were over 75 000 tonnes of harvestable male crabs (with a carapace exceeding 100 mm in width). This means that the total population of snow crab is many times greater.

BIOLOGY

The life history of the snow crab is fairly well known from studies in its natural habitat, but few studies have been done on the snow crab in the Barents Sea. The crab is a typical arctic species that thrives best at temperatures below 4°C but is also capable of living at temperatures down to -1.5°C. Juveniles prefer temperatures below 3°C. The reproductive cycle of the snow crab can span either one or two years, depending on the temperature conditions in the crab's habitat. Spawning and mating take place over an extended period - from January to May - and the old eggs hatch just before the next spawning. The larval stage is pelagic and normally lasts about two months. After settling on the seabed, the larva takes on the form of a tiny snow crab, only about 3.5 mm. The crab grows by shedding its outer shell (moulting) several times until the final (terminal) moult when it becomes sexually mature. It is then usually five years old. Size



A snow crab caught in Olgastredet in 2011.
Photo: Jan H. Sundet



Snow crab range in the Barents Sea based on by-catches of snow crab during the Norwegian–Russian ecosystem research cruise in 2013. The black-edged area indicates roughly where snow crabs were first recorded in the Barents Sea. Red stars indicate finds of individual crabs.

at terminal moult can vary greatly among both males and females, and males are normally considerably larger than females. Snow crabs have been observed at depths from 50 to 450 metres, but most of them are found at between 200 and 300 metres depth, where the crabs prefer to live. There they graze on animals living in and on soft bottom sediments like mud and clay. Several different kinds of prey have been identified in the stomachs of snow crabs, but mussels, polychaete worms and crustaceans appear to dominate. This indicates that the snow crab is not dependent on particular prey species for survival.

FISHERIES

In 2013 and 2014, a substantial snow crab fishery developed in the Barents Sea, with up to 15 large vessels from several countries participating. All the fishing takes place in international waters, and the vessels fish with up to 2 500 crab traps each. The traps are strung together in chains up to several kilometres long, and the large numbers involved have led to conflicts between crab and trawler fisheries in this area.

Most of the snow crab population is in the Russian zone, but this area has hitherto been closed to snow crab fisheries. Since crabs can be processed both shipboard and landed to facilities on shore, it is difficult to obtain a reliable overview of the total volume of the fishery. Snow crab landings in 2014 are expected to total around 4 000 tonnes, which is almost on a par with the tonnage of king crab landed from the Barents Sea. However, the price of snow crab is only 25-30% of the price of king crab.

In view of the fact that the snow crab population may grow much larger than it is at present, we can expect considerably bigger catches once snow crab fisheries are opened up in the Russian zone. Calculations indicate that annual catches in the Barents Sea may amount to between 40 000 and 10 000 tonnes once the snow crab has spread to its full extent.

IMPACT ON THE ECOSYSTEM

Snow crab may thus become a major fishery in the future, but the important question is what role it will play in the ecosystem of the Barents Sea. A species as numerous as the snow crab is expected to become, and that constitutes so much biomass, is clearly bound to affect the existing ecosystem. There is much to indicate that arriving snow crabs will take over a niche in the food web that was previously occupied by a number of different species, primarily bottom-dwelling animals. Snow crabs will affect the ecosystem by feeding on animals that live on the seabed, which may lead to changes in the species composition of bottom-dwellers. Crabs will also compete with - and be eaten by - other animals that find their food on the seabed. Learning more about how snow crabs affect benthic ecosystems in the Barents Sea is essential if we wish predict what changes we can expect.

Arctic marine systems are simpler than ecosystems further south. That also makes them more vulnerable to external factors such as the introduction of non-native, invasive species. Arctic food webs usually only have a few species on each trophic level, making each individual species more important. Impacts on one trophic level can therefore have significant “cascade” effects upwards and downwards in the food web.

A larger proportion of the plant production sinks to the bottom in the Arctic than in southerly waters. Once at the seabed, this sedimentary organic matter is broken down into chemical elements that are then available as nutrients for growth of new plant biomass - and the benthic fauna is responsible for this transformation. Changes in bottom fauna composition and biomass can thus contribute to lower remineralisation of organic matter within the ecosystem.

Today, we are probably seeing only the beginning of the snow crab’s development in the Barents Sea, and a great deal will happen in years to come. Everything suggests that the snow crab will become a significant player in this ecosystem, with all the challenges that will imply for marine research in terms of understanding what is happening. The multidisciplinary research approach that will be required is a suitable challenge for the flagship research programmes at the Fram Centre.

Magnús Jóhannesson // Director, Arctic Council Secretariat

Arctic Council Secretariat a sign of Council's growth

When planning their consecutive chairmanships of the Arctic Council (2006-2013), Norway, the Kingdom of Denmark, and Sweden prioritised setting up a temporary secretariat to help ensure coordination and consistency of the Council's activities. Then, in 2011, the ministers of the Arctic Council decided that the time had come to establish a standing secretariat for the Arctic Council. The standing Arctic Council Secretariat (ACS) was formally established on 23 January 2013, and officially opened for business in Tromsø in June of that year, under the Canadian Chairmanship (2013-2015).

The ACS serves a unique role within the Council, which is not formally an international organisation but rather a high-level forum made up of the eight Arctic states (Canada, the Kingdom of Denmark, Finland, Iceland, Norway, Russia, Sweden and the United States) and six Permanent Participant organisations representing the indigenous peoples of the Arctic. Prior to the establishment of the ACS, administrative duties passed from arctic state to arctic state along with the rotating two-year Chairmanship of the Council. Now that it is a "permanent" establishment, the ACS serves not only as the home base for logistics to support the regular meetings of the Council and to ensure continuity in the work of the Council, but also as the Council's institutional memory. One of its first and most important duties has been to create an institutional archive stretching back to the Council's establishment in 1996. While this requires significant effort and detective work, the end product will help make the Council's history and activities more transparent and available both to the public and to those working within the Council itself. The ACS, in coordination with the Chairmanship, also has a vital role to play in supporting the Council's working groups and task forces, and in developing and expanding the Council's communications and outreach activities.

Arctic Council Secretariat staff. Left to right, back row: Tom Fries, André Skrivervik, Magnús Jóhannesson, Jesper Stig Andersen, Johanna Hämäläinen; front row: Kseniia Iartceva, Patti Bruns, Nina Buvang Vaaja, Vanja Mari Sjursen, Linnea Nordström. *Photo: Linnea Nordström*

The current 10-member ACS team reflects the diversity of the arctic region, hailing from seven of the eight arctic states. In addition to the director (Magnús Jóhannesson of Iceland) and the deputy director (Nina Buvang Vaaja of Norway), two other Norwegians – André Skrivervik and Vanja Marie Sjursen – take care of the office's practical functioning and archiving efforts, respectively. Two Finns – Johanna Hämäläinen and Linnea Nordström – work on administrative issues and communications/website activities, respectively. Of the remaining staff members, Patti Bruns of Canada serves as a coordinator for the working groups ACAP (the Arctic Contaminants Action Programme) and EPPR (Emergency Prevention, Preparedness and Response), Jesper Stig Andersen of Denmark advises the ACS on issues related to decision-making and communication and provides general support to the Secretariat's work, Kseniia Iartceva of Russia provides interpretation and Russian-language services, and Tom Fries of the United States works on communications for the Council.

For the past year and a half, the Secretariat has been working closely with the Canadian chairmanship to support all of its efforts. Work in both Ottawa and Tromsø is ramping up as we head towards the 2015 Ministerial Meeting in Iqaluit. The Iqaluit meeting will consider the achievements during Canada's chairmanship, mark the handover to the chairmanship of the United States and set the Council's agenda for the coming two years. In preparation for the Ministerial Meeting, ACS staff will be consulting on an ongoing basis with colleagues in Canada to provide whatever input is desired in the planning process for the Ministerial events. On the communications front, the ACS will be working within its approved work plan to reach out to arctic communities, journalists, analysts and many other stakeholders as well as through social media to share word of what has been accomplished in the past two years and prepare for the upcoming Ministerial events.

The Secretariat's first year and a half of operation has been a truly exceptional experience for the whole staff, not least because the ACS has the privilege of sharing the Fram Centre with many outstanding research and governmental organisations that are involved in the Arctic. The presence of these "sister" organisations in Tromsø provides a unique perspective that very few locations in the world could offer. Strong support from our Norwegian host, the Ministry of Foreign Affairs, has been invaluable in the development of the ACS, as has recognition from the local authorities in Tromsø and regular interaction with the UiT The Arctic University of Norway.

The natural challenges that attend the development of a new organisation have been greatly outweighed by the pleasures of our work, which requires creativity, innovation, energy and international cooperation. Being part of the establishment of the ACS has been a special opportunity for all of us to learn together and build relationships and expertise. The greatest privilege for me in my role as director over the past year and a half has been working with the extremely energetic and capable staff we have here at the ACS.

Helge M. Markusson // Fram Centre

Norwegian Meteorological Institute joins the Fram Centre

The Norwegian Meteorological Institute's monitoring and research activities in the High North will be important contributions to expanding and strengthening the Fram Centre's expertise.

In October 2014, the Fram Centre's Committee of Institutional Directors and the Ministerial Steering Committee unanimously accepted the application of the Norwegian Meteorological Institute (MET Norway) to become a full member of FRAM – High North Research Centre for Climate and the Environment (the Fram Centre).

"That MET Norway is becoming a member of the Fram Centre is good news for us," says Jan-Gunnar Winther, chair of the Fram Centre's Committee of Institutional Directors. "MET Norway's monitoring and research activities in the High North will be important contributions to expanding and strengthening the Fram Centre's expertise. We are also looking forward to closer cooperation with a central government institution that belongs to the Ministry of Education and Research."

IMPORTANCE OF THE HIGH NORTH

"The research done at the Fram Centre is important in order to ensure that MET Norway's operational services are based as far as possible on observations and process knowledge in the areas we provide weather forecasting services for – Norway and its adjacent seas. This is where the High North is important," explains Øystein Hov, Director of Research at MET Norway.

LEADING

The Meteorological Institute was established in 1866 and is today a leading international centre of excellence in weather forecasting and climatological research. MET Norway, as it is now known, has its head office in Oslo and branches in Bergen and Tromsø. Operations are divided into three divisions: Weather Forecasting Services, Research and Development, and IT.

MET Norway forecasts weather on land and at sea, calculates prognoses for the extent of sea ice, maps climate trends over the past hundred years, and makes projections for future trends, as well as calculating environmental impacts associated with pollution on land and at sea.

"MET Norway has excellent channels of communication to the general public and to important sectors of society, and through our membership of the Fram Centre we will be able to do even more to help make the social benefits of the Centre's research more clearly evident," says Øystein Hov.

Pedro Duarte and Dmitry Shcherbin // Norwegian Polar Institute
Tore Hattermann // Akvaplan-niva
Jonas Juselius // UiT The Arctic University of Norway
Evgeniy Yakushev // The Norwegian Institute for Water Research

Ecosystem modelling of the Arctic Ocean around Svalbard (ArctisMod) – a new ecosystem modelling project at the Fram Centre

In recent years, the Arctic Ocean has shifted from being dominated by multi-year ice, to first-year ice. Warming, acidification and a retreating summer sea ice cover together with increased land drainage lead to potentially important changes in the ocean's ecosystem.

Such changes are important partly because they are likely to have impact on *ecosystem services*, that is, the benefits the ecosystem has to offer. The complexity of feedback links between the physical, chemical and biological processes in the ocean make it difficult to predict future trends. However, with computer models, we can simulate many different scenarios, allowing more accurate predictions.

In April 2014 the new Fram Centre project ArctisMod under the "Arctic Ocean" flagship started, with the objective of adding biogeochemical processes and their interactions with the physical processes to a physical model developed previously under another project within the same flagship, namely "Mesoscale modelling of ice, ocean and ecology of the Arctic Ocean" (see page 58).

To achieve its goals, the ArctisMod project depends on several independent computer models, which must be able to assimilate and exchange data between one another. The coupling of the required models is facilitated through the SYMBIOSES framework. SYMBIOSES was originally designed for coupling oceanography (transport), aquatic and oil fate models to provide simulation data for ecosystem-based management processes.

The original SYMBIOSES framework was largely targeted at particle-based (Lagrangian) models. However, Lagrangian models are most suitable for tracking transport from point sources, and the ArctisMod project needed a grid-based (Eulerian) model that was better at handling movement of biogeochemical

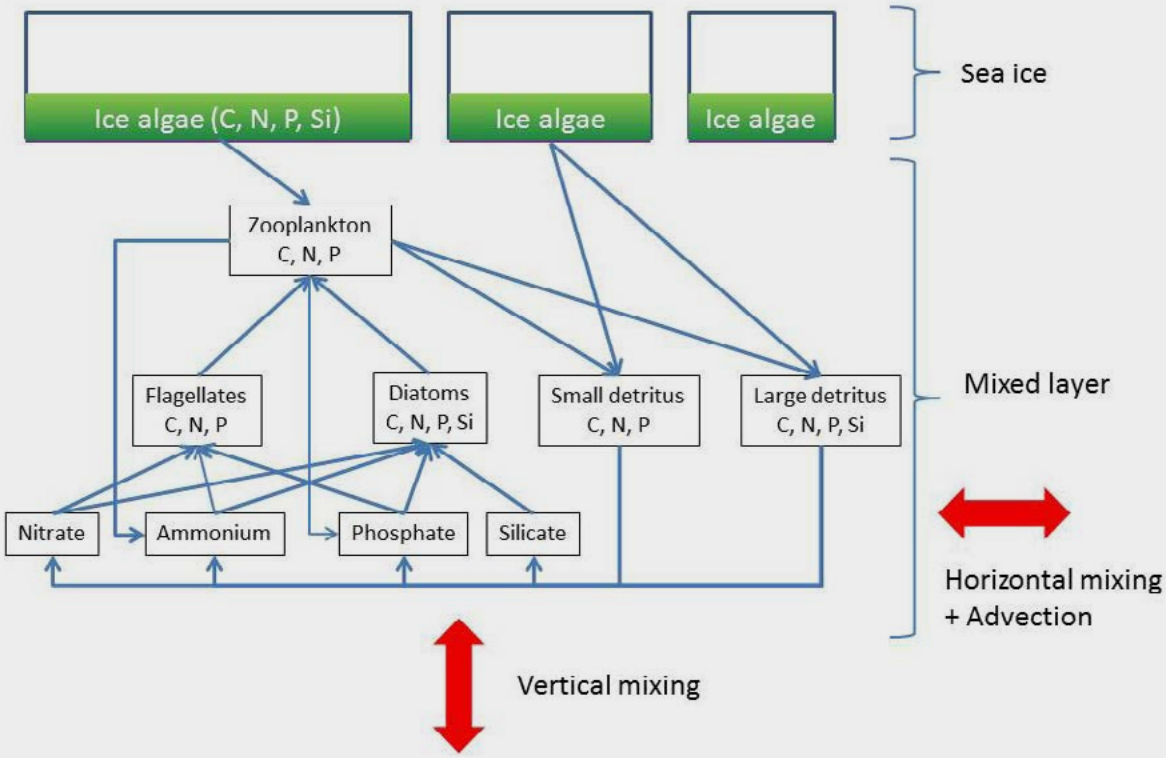


Figure 1 – The main variables and processes considered in the biogeochemical model. Nutrients dissolved in sea ice are not presented here, though they are included in the model.

species over larger areas. The SYMBIOSES framework has therefore been extended with procedures allowing direct access to both the internal grids and the transport mechanisms of the hydrodynamic model component. Using the new interfaces, the existing models ROMS and EcoDynamo are being coupled to SYMBIOSES.

The ArctisMod project will initially include low trophic levels and biogeochemical cycles in the water and in the sea ice (Figure 1). The computer code necessary to simulate biogeochemistry is partly available in ROMS code and partly available in EcoDynamo, an object-oriented modelling software already in use at the Norwegian Polar Institute. Attempts will be made to use several "currencies" in the model: carbon, nitrogen, phosphorus and silica. This will allow bookkeeping calculations of ocean stoichiometry, which provide an important quality control of the model results.

One of the main challenges is the simulation of sea ice processes. The plan is to use the Los Alamos Sea Ice Model "CICE" both for ice physics and biogeochemistry. Results obtained recently with an ice algal model developed at the Norwegian Polar Institute emphasise the importance of resolving the vertical variability of physical and biogeochemical ice processes. CICE does this for the physical processes, and includes a biogrid developed to handle biogeochemical processes.

Figure 1 is a simplified representation of the variables and processes included in the biogeochemical model under preparation. It is important to emphasise that these variables and processes will be represented in the same three dimensional grid used for the circulation model already implemented for the Arctic Ocean. This will provide the velocity field to transport both

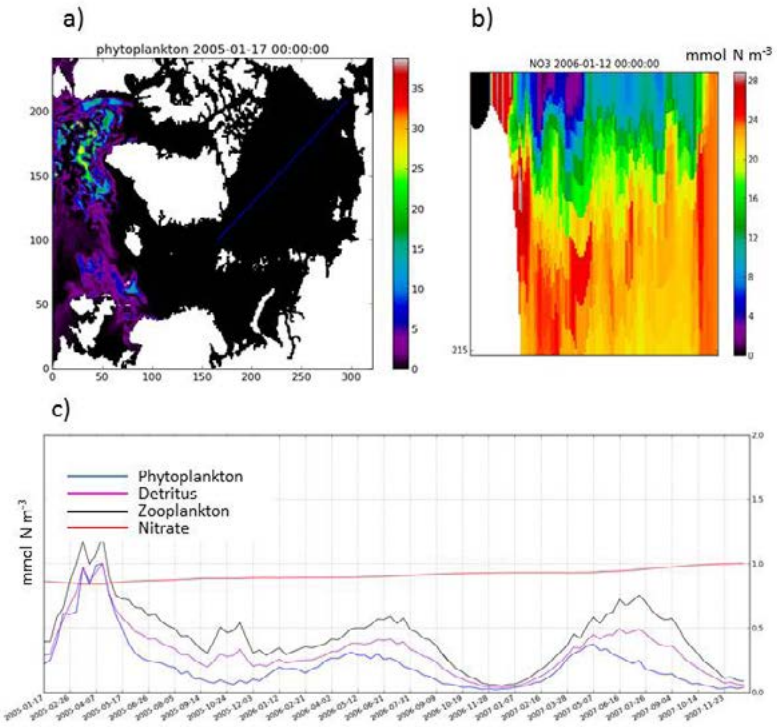


Figure 2 – The model domain, shown in panel a), includes the Arctic Ocean, the Barents Sea and part of the North Atlantic. Also shown is a transect line (blue) along which some model outputs for nitrate are presented in panel b) as a function of depth. Panel c) shows the model predicted average concentration of several variables for a period of almost three years.

pelagic variables and ice floes across the model domain. Biogeochemical processes in the water and in the ice are represented by similar variables. Figure 2 shows the model domain and some outputs of the first coupled physical-biogeochemical simulations.

The modelling work described here should be seen as an ongoing process that will benefit from continuous improvements, as our understanding of relevant processes and variables builds up. One crucial aspect is quality control of model results. Assurance may only be achieved through systematic comparisons of hindcast simulations with real data and measures of how well the model predicts them.

ARCTISMOD – MODEL SETUP AND INPUT

The flagship research program “Arctic Ocean” focuses on the central Arctic Ocean and the ice-affected areas of its adjacent seas. One goal is to improve predictions of the changing structure and function of ecosystems in ice-affected waters, enabling better assessment of future living marine resources and more reliable predictions of the extent, thickness and quality of the ice cover. The Fram Centre Scientific Program prioritises “developing a state-of-the-art model with a resolution of 4 km for the Arctic Ocean and 800 m around Svalbard”. Such a model is currently being developed by several Fram Centre partners within the project “Mesoscale modelling of ice, ocean and ecology of the AO”. The model simulates ocean circulation and ice dynamics, using the Regional Ocean Modelling System (ROMS) code. The ArctisMod project builds upon this model, adding biogeochemical processes and their interactions with the physical processes. ArctisMod is led by the Norwegian Polar Institute, with the participation of Akvaplan-niva, UiT The Arctic University of Norway and the Norwegian Institute for Water Research. Implementing such models requires deep understanding of ecosystem processes. Current understanding of the biogeochemical processes in the Arctic Ocean is limited by the relative scarcity of data. Therefore, the ArctisMod project relies not only on the best available knowledge, but also on ongoing surveys. During the ongoing N-ICE2015 survey, the Norwegian Polar Institute’s research vessel Lance will drift with pack ice north of Svalbard collecting important data that will later be used for model parameterisation, calibration and validation. During another recent cruise, experiments were carried out to collect data on how arctic phytoplankton respond to light intensity, as well as on zooplankton respiration and grazing rates. These data will also be used to parameterise phyto- and zooplankton sub-models.

Christine F. Solbakken // NILU – Norwegian Institute for Air Research

Record high levels of siloxanes released into Tromsøysund

That nice, silky smooth feeling you get when you rub yourself with lotion after the shower comes from chemicals called siloxanes. Scientists find these same substances in hair shampoo, cleaning products, car wax – and in cod caught in Tromsøysund.

"The siloxanes we found in cod collected outside Tromsø comes partly from soap, shampoo, skin creams, and various other personal care and cleaning products we use," explains senior researcher Nicholas Warner at NILU - Norwegian Institute for Air Research at the Fram Centre.

"We flush the substances down the drain," Warner continues, "and although the water treatment plants capture some of it, significant amounts are still discharged into the aquatic environment. In Europe alone, siloxane emissions are estimated at over 20 kilotons per year."

The substances, with simple abbreviations and complicated names such as D4 (octamethylcyclotetrasiloxane), D5 (decamethylcyclopentasiloxane) and D6 (dodecamethylcyclotetrasiloxane), are used in cosmetics, personal care products and cleaning products that most of us have at home.

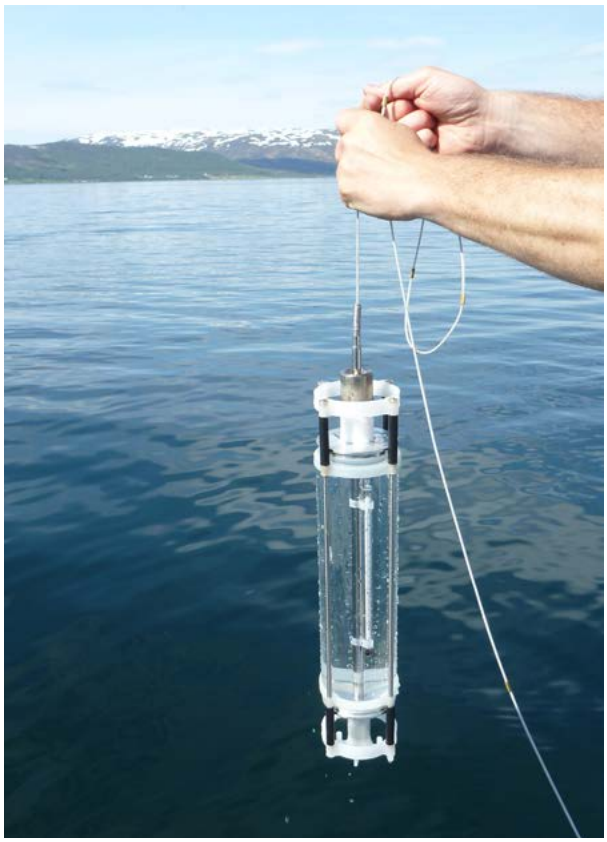
D4 used to be an important ingredient in personal care products until a few years ago, when it was discovered that it induced toxic effects in several organisms. Therefore, production has shifted to use less D4 and more D5 in these products - and scientists are now finding very high concentrations of D5 in the aquatic environment.

RECORD-BREAKING LEVELS

Collecting water and sediment samples from wastewater emission sites around Tromsøysund during the autumn of 2014, the NILU scientists have further investigated the siloxane exposure levels to the local aquatic environment.

"We have found extremely high concentrations of siloxanes in wastewater effluent," Nicholas Warner explains. "The concentrations ranged between 100 and 10 000 nanograms per litre in wastewater effluent collected from outlets in Tromsø. The highest concentrations were of D5, which is the dominant siloxane used in personal care product formulations."

D5 is also used in biomedical and cleaning products. Thus, it is not surprising that the levels observed in the outlet that receives waste from the local hospital were six to ten times higher than in other wastewater outlets. It was more surprising that the concentrations found were significantly higher in samples from Tromsø than in samples from British cities with much larger populations.



Collection of surface water from Tromsøysund.

Photo: Nicholas Warner, NILU

Water sample preparation for siloxane analysis.

Photo: Nicholas Warner, NILU

INFRASTRUCTURAL IMPACT

How can this be? Warner and his fellow scientists believe the answer may be found in differences in wastewater treatment capacity. Many wastewater treatment plants in larger cities employ higher levels of treatment (secondary or tertiary).

However, Tromsø, and many other communities in northern Norway, have minimal or no wastewater treatment to aid in the removal of these chemicals. In addition, the population of Tromsø has increased by 20% over the last 15 years, while the wastewater treatment infrastructure has remained essentially the same. Thus, despite Tromsø having a smaller population than large European cities, the town releases larger amounts of siloxanes to the local environment.

ACCUMULATION IN SEDIMENT

Siloxanes were also detected within the sediment, with concentrations ranging between 10 and 30 nanograms per gram sediment. These concentrations are lower than in lake environments impacted by wastewater emissions, currently being investigated by Warner and colleagues under the NORDIC LACS project (Nordic Lake exposure to Cyclic Siloxanes: Assessment of transport, distribution, and fate) funded by the Research Council of Norway. In Storvatn, Hammerfest, concentrations were as high as 100 nanograms per gram sediment, even though the population is considerably smaller than Tromsø's.

"This difference in sediment concentration can be attributed to the strong water currents in Tromsøysund," says Warner. "A strong current allows fast water exchange, where siloxanes attached to particles within the water column are transported away from Tromsøysund. High water turnover may also further enhance volatilisation of siloxanes from the water column to the atmosphere."

In addition to studying water and sediment samples, the scientists have dissected cod caught in Tromsøy-

sund, collecting samples of liver and muscle tissue. Where possible, they have also collected the gonads - the reproductive organs - of the fish.

"Earlier laboratory experiments using mice showed preferential accumulation in sex-related organs," says Warner. "It would be interesting to see if accumulation of siloxanes also occurs within the reproductive organs of fish, and if so, if this poses an increased risk to reproductive performance."

MANY STUDIES, FEW ANSWERS

Studies of lakes in Norway have shown that D5 accumulates up the aquatic food chain, but similar studies done in Canada have found contradicting results. To the researchers at NILU, this suggests that other factors may be important for how siloxanes accumulate in fish and other aquatic organisms.

Sediment grab being lowered for sediment collection from Tromsøysund.

Photo: Nicholas Warner, NILU

One reason for the conflicting results may be that the siloxane levels in fish range widely, as the scientists have shown. Warner and his colleagues think this variability could be related to the species in question, what development stage the fish is in, and how large it is; they base this surmise on research they recently published in *Environmental Pollution*.

"Our results showed an association between cod length and weight, and D4 and D6 levels," explains Warner.

"We believe this is because the cod is able to eliminate or dilute its D4 and D6 concentrations as it grows. Metabolism and the ability to eliminate siloxanes appears to increase with fish size, but we found no relationship between cod length and weight and levels of D5."

This may be due to the high exposure to D5 in the environment, making it impossible for the cod to eliminate D5 as fast as D4 and D6, and allowing D5 to remain in the fish over a longer time. Thus, the risk of adverse effects is greater, and the need for further research more pressing.

FURTHER READING:

Warner NA, Nøst TH, Andrade H, Christensen, G. (2014) Allometric relationships to liver tissue concentrations of cyclic volatile methyl siloxanes in Atlantic cod. Environmental Pollution 190:109-114. doi: 10.1016/j.envpol 2014.03-031

WHAT IS SILOXANE?

Siloxanes are used in various industrial applications ranging from cosmetics and hygiene products to car wax, detergents, fuel additives, and anti-foaming agents. The use of siloxanes is extensive and consumption may increase in the future.

Siloxanes are found in several varieties, including D4 (octamethylcyclotetrasiloxane), D5 (decamethylcyclopentasiloxane) and D6 (dodecamethylcyclotetrasiloxane).

Research shows that some siloxanes may have environmentally hazardous properties in that they break down slowly and that they accumulate in living organisms. Siloxanes are emitted to both water and air, where they can be transported far by air currents, and bind to particles within the water column or accumulate in sediments and increase exposure of aquatic organisms.

NILU AND SILOXANES

Researchers from NILU were the first to find siloxanes in the arctic environment, when they found high siloxane levels in arctic fish and sediment near the communities in Svalbard (Warner et al. 2010). Scientists have also shown that siloxanes are transported to Svalbard by air currents coming from more polluted areas (Krogseth et al. 2013).

NILU has also conducted research on human exposure to siloxanes in Norway. Concentrations in human blood and plasma are low compared to those found in fish and other marine creatures (Hansen et al. 2013).

ABOUT THE PROJECT

The research project on siloxanes in cod is funded by NILU and the flagship project "Emission, exposure, and residence times of cyclic siloxanes". Preliminary results have been obtained from a study investigating the relative accumulation potential of siloxanes and PCBs in cod, and the relationship between siloxane concentrations and fish length and weight. These results have been published in the journal *Environmental Pollution*.

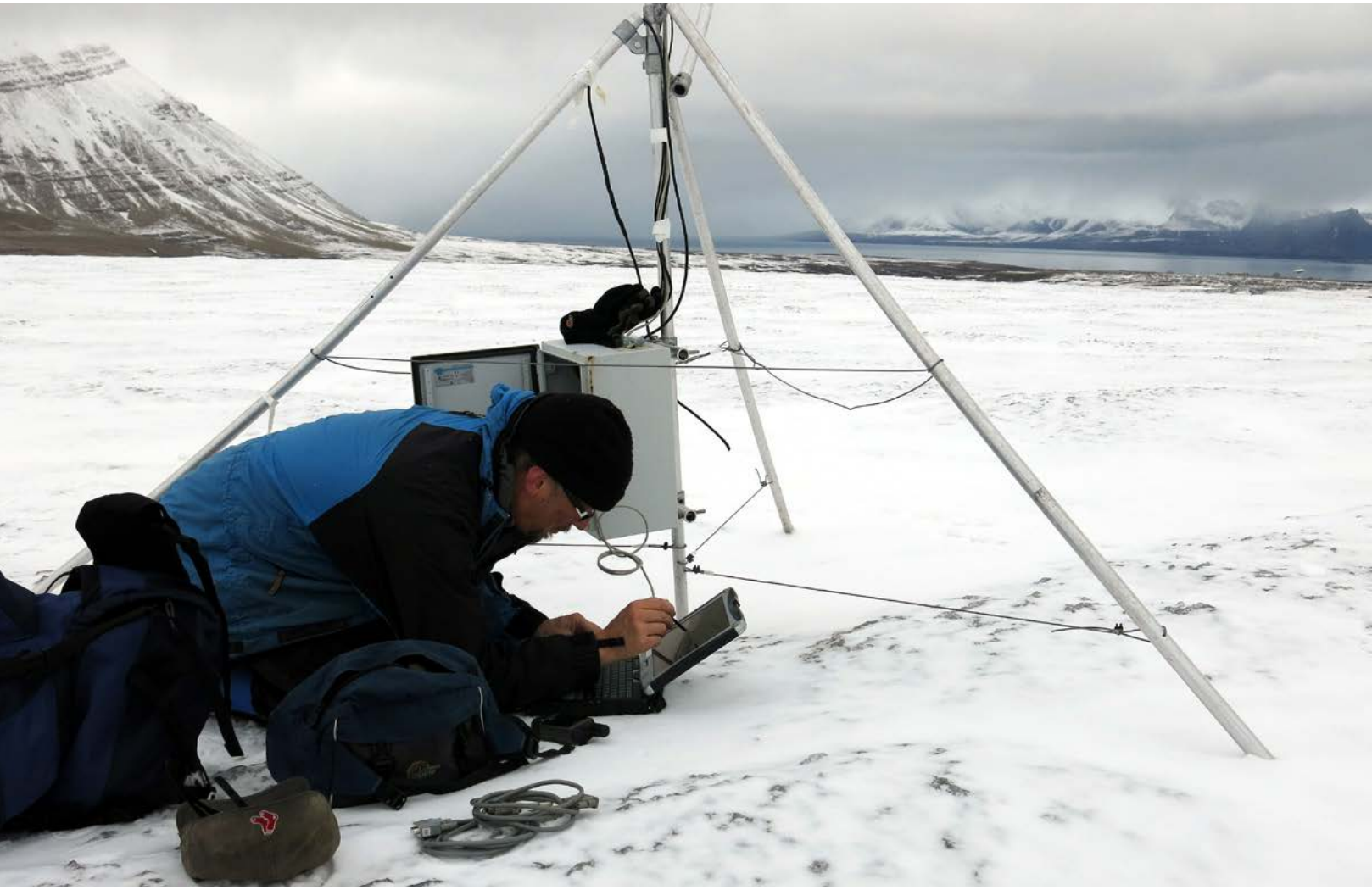
Helge M. Markusson // Fram Centre

Research at the end of the earth

Ny-Ålesund is the most northerly permanent civilian settlement in the world. Here, at 79°N, twenty nations are conducting research projects, and now Ny-Ålesund is full.

The Norwegian Mapping Authority's geodetic earth observatory must tolerate harsh conditions. The new observatory is being constructed down the hill, north of the existing station.

Photo: Helge M. Markusson, Fram Centre



Checking instruments near Ny-Ålesund.
Photo: Max König, Norwegian Polar Institute

It's an autumn evening in Ny-Ålesund in Svalbard and the normal working day is long over, but in a second-floor office in the Sverdrup station, a glaciologist is still immersed in his work. "It's essential to spend my time here as effectively as possible, which makes for very long working days," Jack Kohler explains.

Kohler is the fourth in a row to be monitoring mass balance on the glaciers around Kongsfjorden. The Norwegian Polar Institute has been taking measurements on these glaciers ever since 1967, which makes the data series one of the longest in arctic regions.

His main project has involved measuring the changes in the glaciers, how much snow falls on the glaciers in winter and how much melts in summer. Twice a year, Kohler comes from the Norwegian Polar Institute's head office in Tromsø to the Institute's research station in Ny-Ålesund. In the winter, he and his assistants set out collapsible aluminium rods, and the following autumn he returns to measure how much ice and snow have melted. The thickness of the glaciers ranges from 50-60 to 600 metres.

"The glaciers are definitely getting smaller, and most of that is due to the increase in temperatures in Svalbard. Even though it can snow a lot on the glaciers in winter, that doesn't compensate for the increasing temperature," says Kohler.

To get to and from the Kongsbreen and Kronebreen glaciers in the autumn, the scientists use a helicopter. In winter, they mostly use snow scooters, provided the glacier is within two hours' drive each way.

If necessary, a helicopter can transport scientists to and from sites near Ny-Ålesund for fieldwork.

Photo: Helge M. Markusson, Fram Centre

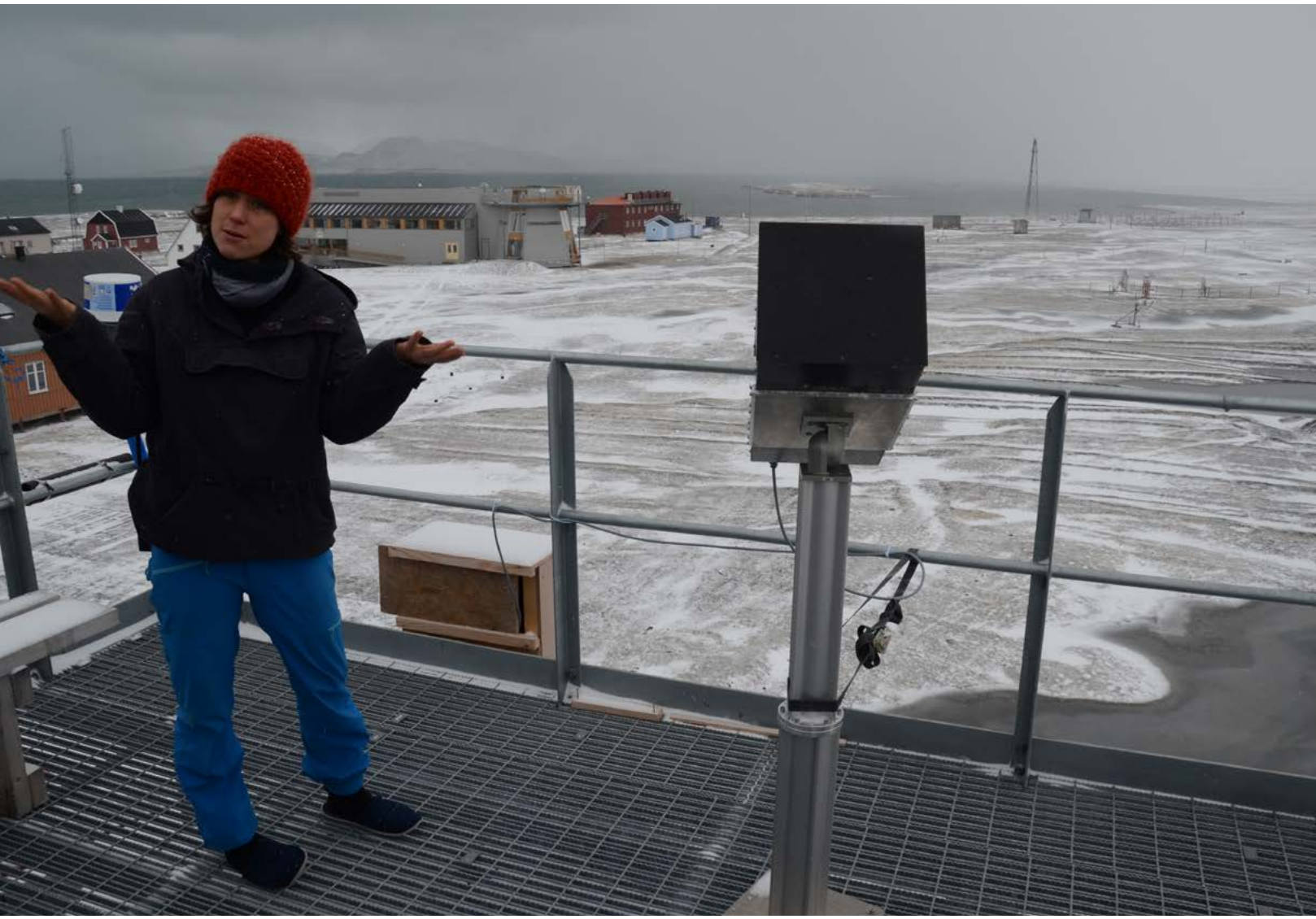
If they need to go further than that, the helicopter is preferable.

"The alternative is to set up camp with tents, with everything that involves, including posting a lookout for polar bears. We've seen bears on the glaciers a number of times," Kohler adds.

Sverdrup station, inaugurated in 1999, is not the only research station in Ny-Ålesund. Walking through this community, you may be reminded of a district in a much bigger city –namely the streets around the United Nations Headquarters in New York, where countless countries are represented with their buildings.

In 1968, the Norwegian Polar Institute was the first institution to establish an all-year research station here. Today, Ny-Ålesund is also home to manned research stations from Germany, France, the Netherlands, the United Kingdom, Italy, India, China, South Korea and Japan. Some twenty nations have research projects in and around the world's northernmost settlement, though not all of these nations have activities year-round. Germany and China do, though. Since 1991, the Alfred Wegener Institute has operated the Koldewey Station, which is engaged in biological and atmospheric research. The Polar Research Institute of China opened the Yellow River Station in 2004, and conducts research on the atmosphere, northern lights, biology, glaciology, geology and marine biology.

Above this cluster of research stations soars the mountain Zeppelinfjellet, with the Zeppelin Observatory 475 metres above sea level. This research



Several countries have established research stations in Ny-Ålesund. Verena Mohaupt is standing on the roof of Germany's research station, which is run by the Alfred Wegener Institute.

Photo: Helge M. Markusson, Fram Centre

station is key to monitoring the global atmosphere. The data collected here are central in mapping climate change, changes in stratospheric ozone and UV radiation, and environmental toxins and air pollutants transported over long distances. The station building is owned by the Norwegian Polar Institute, while NILU – the Norwegian Institute for Air Research, has scientific responsibility for the station.

And down by the harbour, on Kongsfjorden, lies the well-equipped Marine Laboratory, operated by Kings Bay, the company that runs the entire town. The marine lab was opened 10 years ago, and there is now periodically a waiting list to book working space here. (For example, much of the work described in the article on page 45 was done in the marine lab.) There is currently discussion about erecting a similar laboratory for non-marine scientific disciplines in Ny-Ålesund.

"We need more and bigger shared laboratories," explains Kim Holmén. As a climatologist, previously employed at NILU, and now International Director at the Norwegian Polar Institute, he knows the conditions at Ny-Ålesund extremely well.

"This year it's become quite clear that the marine lab is too small. Several of the research stations have had to resort to improvised workspaces that are far from satisfactory. But here we find several dilemmas cropping up: increased activity will increase the amount of stray light, which can perturb important optic measurements in the winter, but on the other hand, more activity will give Kings Bay stronger

Ny-Ålesund is considered the northernmost settlement in the world. Conditions at almost 79°N challenge both those who live there and those who operate the infrastructure – Kings Bay AS.
Photo: Helge M. Markusson, Fram Centre

NY-ÅLESUND

Ny-Ålesund, 78°55'00"N 11°56'00"E is the world's northernmost permanent civilian research station and has developed into what is today a modern, international, arctic scientific research and environmental monitoring base.

Up until 1962, Ny-Ålesund was a coal-mining town, but mining ceased following a major accident. Since 1964, Ny-Ålesund has been built up and developed as a centre of international arctic research and environmental monitoring.

Several countries have research stations in the village. During the summer season, research activity is high and the population mushrooms to 150 people, versus only about 35 in the winter.

Several of the Fram Centre's research institutions have considerable activity in and around Ny-Ålesund: the Norwegian Polar Institute, the Norwegian Mapping Authority, NILU – the Norwegian Institute for Air Research, UiT The Arctic University of Norway, the University Centre in Svalbard, and the Norwegian Institute for Nature Research.

The infrastructure and the Marine Laboratory in Ny-Ålesund are operated by Kings Bay AS.

Kongsbreen glacier in September 2014.
Photo: Jack Kohler, Norwegian Polar Institute

At the marine lab, a team of Spanish researchers are studying carbon metabolism in seaweed. During some seasons, the lab is full to capacity.
Photo: Helge M. Markusson, Fram Centre

economic legs to stand on. The new fibre-optic cable to Ny-Ålesund will mean greater capacity to carry out remote sensing and less need for researchers to be physically present for long periods. At the same time, the cable will result in increased activity. We need to grow in terms of quality rather than in the number of scientists in the village," says Holmén.

Christina A. Pedersen, research coordinator at the Norwegian Polar Institute, elaborates: "The main problem is that an increase in activity will lead to an increase in emissions. On the one hand, we want to offer the excellent opportunities we have in Ny-Ålesund to all other researchers, but on the other, it is incredibly important that we don't affect the surroundings and the conditions we're measuring, so that we draw faulty conclusions as to the causes of observed changes. This is our dilemma."

And speaking of size and quality, the decidedly largest project as regards research facilities in Ny-Ålesund was initiated last year.

On 4 October 2014, Jan Tore Sanner, Norwegian Minister of Local Government and Modernisation, drove the first foundation pile into the ground for the Norwegian Mapping Authority's new geodetic earth observatory at Brandallaguna just outside Ny-Ålesund. From here, the Mapping Authority will monitor minute changes in the earth, contributing to providing a framework of reference for climate research, mapping, satellite orbits, GPS systems, and for navigation and positioning services. After a period of overlap, the existing geodetic station by the airstrip will be phased out.

Per Erik Opseth, Director of the Norwegian Mapping Authority, says: "In 2018, we will deliver a world-class geodetic earth observatory. Ny-Ålesund will host a station that is one of the foundation stones in the global infrastructure designed to support more accurate monitoring of sea-ice melt and sea levels, among other things."

The new station, which will be the most northerly of its kind in the world, has a cost framework of NOK 300 million.

The international significance of this project was also emphasised by Dr. Rajendra Pachauri, Chairman of the United Nations Intergovernmental Panel on Climate Change, when he visited Ny-Ålesund at the end of June 2014.

"Geodetic earth observation will make us better equipped in our struggle to find solutions to the challenges of climate change," said Dr. Pachauri

Alf Håkon Hoel // Institute of Marine Research
Tore Henriksen // UiT The Arctic University of Norway

Fisheries in the Arctic Ocean?

Globally significant fisheries take place in the seas surrounding the Arctic Ocean. Pollock fisheries in the Bering Sea and cod fisheries in the Barents Sea are major fisheries even in a global perspective. Global warming has numerous repercussions on marine ecosystems, and the northwards expansion of fish stocks can be related to changes in ocean temperatures. In the Central Arctic Ocean, reduced ice cover represents a major change to ecosystems. An important driver in the geographic expansion in fish stocks in the Northeast Atlantic is also successful management. The larger a fish stock is, the more space it needs to find food. These developments, and reduced ice cover in particular, have prompted speculations that commercial fisheries might occur also in the Central Arctic Ocean.

The Arctic Ocean proper ("Central Arctic Ocean") is to the north of the landmass of the five coastal states the Russian Federation, USA, Canada, Denmark/Greenland and Norway. In the middle of the Arctic Ocean, a 2.8 million km^2 area is beyond the jurisdiction of the five coastal states. Here, it is expected that summer ice will continue to be reduced in the years ahead and eventually largely disappear (by early fall) in mid-century.

A number of conditions have to be met for stocks of living marine resources to extend their range into new areas. They need suitable water temperatures, food must be present, and spawning grounds should not be too far away. These conditions, as well as others, are not found the deep Central Arctic Ocean for groundfish like cod and haddock, which do not thrive in deep waters. Pelagic species that live in the water column, such as polar cod, could, however, migrate into the deeper waters. In the US in particular there has been a concern that vessels from distant water fishing nations may take the opportunity to start unregulated fisheries in the high seas beyond the 200 mile zones, should the areas become ice-free and the resources become available. Parts of this area, off Alaska and Northeast Russia, have been ice-free in summer in recent years.

This prospect has sparked a debate on how hypothetical future fisheries in the area beyond national jurisdiction should be managed. The five coastal states have considered this question for several years. The existing international legal framework for the oceans (which in this context is centered around the 1982 Law of the Sea Convention and the 1995 UN Fish Stocks Convention) require states to cooperate on resource management in areas beyond national jurisdiction. In the Northeast Atlantic, the Northeast Atlantic Fisheries Commission, a Regional Fisheries Management Organisation, has a mandate that extends to the North Pole, while the rest of the high seas in the Central Arctic Ocean is not subject to such an arrangement.

Of particular concern is the possibility of a new fishery starting in this area, one involving harvest of a *straddling* fish stock (i.e. one that spends time in the exclusive economic zone of more than one state) or a *highly migratory* fish stock (i.e. a species defined as such in an annex to the Law of the Sea Convention). If this were to happen, the Fish Stocks Agreement states that the countries involved must cooperate with a view to establishing arrangements to ensure the conservation and management of the stock. Because of uncertainties regarding the size and productivity of the stock and the impacts of the fishery on the ecosystem, the states involved in the fishery would be obligated to apply the *precautionary*

approach, which implies a requirement to adopt, as soon as possible, cautious conservation and management measures, including limits on catch and catch efforts.

A first meeting among government officials of the five coastal states was held in Oslo in 2010. The meeting resulted in a request to marine research institutes to assess the situation for fish stocks in the Arctic Ocean, and to review relevant research. A follow-up scientific meeting took place in Anchorage the year after, and concluded that commercial fisheries are unlikely to emerge in the Central Arctic Ocean in the short term. The meeting also emphasised the need for research and monitoring in this area.

A second meeting of government officials took place in Washington D.C. in 2013. This meeting asked for additional information from the scientists, in particular on the probability of commercial fisheries developing in the areas beyond national jurisdiction in the Central Arctic Ocean. The meeting also initiated a discussion on management measures, including interim measures to prevent potential unregulated fisheries. Following up on this, a second meeting of scientists was held in Tromsø later that year, addressing current monitoring and research efforts and arrangements for surveying the marine ecosystems in the Arctic Ocean. The Tromsø meeting also provided recommendations on how scientific monitoring could be enhanced and how questions regarding expansion of fish stocks into the Central Arctic Ocean could be addressed.

In February 2014, government officials met again in Nuuk. Here, they agreed that more scientific research is needed to better understand the living marine resources of the Arctic Ocean, and that a scientific program for this should be established. Furthermore, the meeting agreed that interim measures to prevent the development of illegal, unregulated and unreported (IUU) fishing in the area beyond the 200 mile zones in the Central Arctic Ocean should be introduced. A third outcome of the meeting was that a broader process involving more countries will be initiated, possibly having a legally binding international agreement as its outcome. So far, Norway is the only country that prohibits vessels flying its flag to fish in unregulated waters beyond national jurisdiction, including those of the Central Arctic Ocean.

What lessons could be drawn from this? Even with a continued reduction in ice in the Central Arctic Ocean, potential future fisheries here are likely to remain within the 200 mile zones of the coastal states. The five coastal states are all major fishing nations and have extensive management regimes for their fisheries. Where fish stocks are shared between two countries, there are bilateral arrangements for cooperation on their management, such as the bilateral Norway–Russia fisheries commission. Also, regarding scientific research, the North Atlantic region already has the International Council for the Exploration of the Sea, established in 1902, whose Arctic Fisheries Working Group provides advice for the management of fish stocks in the High North. What the coastal state process described above adds to this established system, is a commitment on the part of the five coastal states to prevent vessels flying their flag from engaging in unregulated fisheries on the high seas in the Central Arctic Ocean. That is, should a situation emerge where fish stocks are actually present there.

In a broader perspective, perhaps the most important aspect of the evolving process described here is that the five coastal states are now working to establish scientifically based, precautionary measures to reinforce and further develop the existing legal-political order in the High Arctic.

Åshild Ønvik Pedersen // Norwegian Polar Institute
Bård-Jørgen Bårdsen // Norwegian Institute for Nature Research

Hunting statistics as a source of new knowledge about Svalbard reindeer

Over the past 30 years, hunters in Svalbard have collected considerable amounts of data on the Svalbard reindeer. Close cooperation between hunters, wildlife management and research is providing new knowledge about these animals.

Photo: T. Nordstad

When the first whalers arrived in Svalbard in the 17th century, reindeer roamed over large parts of the archipelago. But by the beginning of the 20th century, intensive hunting had driven them almost to the verge of extinction. In 1925, the Svalbard reindeer was given protected status, and since then reindeer populations have increased and re-colonised many of their former habitats. In 1983, it became permissible to hunt reindeer for research purposes, and as of 1989 an annual hunting quota ranging between 117 and 235 animals has been distributed by lottery among permanent residents of Svalbard. As part of the post-harvest reporting, hunters are required to deliver a hunting report along with the lower jawbone of the animal they have shot. This has resulted in the formation of a database consisting of information about individual reindeer, currently covering about 80% the animals killed since 1983 (about 4200).

JAWBONES AS A MEASURE OF ENVIRONMENTAL CHANGE

In ungulates, body mass is usually used as a measure of body condition. Body mass is closely related to

Photo: Ruben Eidesen

reproductive and survival capability, but in Svalbard there is no obligation to report the slaughter weight of reindeer. We therefore wanted to examine whether the length of a reindeer's jawbone was an appropriate measure of the animal's body condition, and could be related to its growth conditions. The jawbone of a female reindeer continues growing until the animal is 3-5 years old; in males, jawbone growth continues to age 5-6 years. In our research project, we compared the lengths of the animals' jawbones with their slaughter weight, and found a strong correlation between these two measures of condition, especially in animals that were still growing. Jawbone length can thus be an alternative measure of body condition, which - like other, more commonly used measures - can be related both to variations in climate and to population density.

SIGNALS OF CLIMATE CHANGE

Svalbard is the part of Europe that has experienced the greatest increases in temperature - both summer and winter - over the past three decades. Rainfall in winter can cover grazing areas with ice, making it difficult for reindeer to find food and impairing their ability to survive and reproduce. Warmer summers, on the other hand, appear to have the opposite effect, although the net effect of these seasonal changes is as yet unknown. The reindeer jawbones provide information from six different hunting areas from 1983 onwards, and form a good point of departure for studying how the natural environment affects the animals' growth conditions. For example, the weather can affect reindeer calves indirectly, through the adult female's response to the environmental conditions during gestation (e.g., extremely bad winters can also result in fewer females reproducing) or directly, by determining summer conditions during the calf's first year of life. On this basis, we tested and found that the jawbone length of both calves and young animals showed negative correlations with winter rainfall events and positive correlations with warm summers.

RELEVANCE FOR WILDLIFE MANAGEMENT

The Svalbard reindeer are monitored annually in Nordenskiöld Land and in the hunting areas. The census provides information about the population's sex and age structure and mortality. When these time series are combined with data collected by the hunters (lower jawbones and hunting reports) and with harvesting data, it gives us supplementary information about individuals as well as populations. This information increases our understanding of how the Svalbard reindeer responds both to variations in climate and to other changes in the natural environment. The hunters'

Map of the six hunting areas (815 km^2) in Nordenskiöld Land, Svalbard.

Map: Oddveig Øien Ørvoll, Norwegian Polar Institute

contribution to this research is a good example of how information from hunters, wildlife managers and researchers helps generate new knowledge of relevance for reindeer management.

Vebjørn Veiberg (Norwegian Institute for Nature Research, Trondheim) and Brage B. Hansen (Norwegian University of Science and Technology) are also involved in the research described here. The project is funded mainly by the Svalbard Environmental Protection Fund.

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Birgit Njåstad // Norwegian Polar Institute

Disseminating knowledge to government agencies and decision-makers

A great deal of time and money is spent every year on acquiring scientific knowledge – both nationally and globally – that is relevant for Norwegian government agencies engaged in environmental and wildlife management. The Norwegian Polar Institute and the other institutions at the Fram Centre are important contributors to this process. The primary task is to acquire and make available knowledge about Norway's northern and southern polar regions.

Government agencies and decision-makers need clear, lucid information quickly, along with information on the current status of scientific knowledge, as a basis for the work they have to do. They rarely have time to plough through mounds of scholarly publications. As a result, the knowledge-generating institutions themselves must find effective ways of disseminating current knowledge in a targeted, easily accessible and scientifically robust manner.

Traditionally, disseminating knowledge to government agencies and decision-makers has been done by producing thematic syntheses and status reports. But given that the knowledge base is constantly developing and more knowledge is constantly being produced, these reports quickly become outdated. Internet-based channels provide completely new opportunities to establish dynamic knowledge dissemination systems that ensure access to continually updated knowledge in areas of interest to government agencies. Establishing such systems is not without its challenges, and considerable effort is required to ensure scientific robustness and a system that can be kept updated at all times. Information that is published on the Web – especially when it comes from established knowledge providers – will be perceived as accurate and up-to-date. Once a system has been set up, arrangements must be in place for continual maintenance, without underestimating the costs involved (time and money).

The following is a brief overview of some important web-based knowledge dissemination initiatives aimed at government agencies that the Norwegian Polar Institute is involved in and is focused on.

State of the Environment Norway (Miljøstatus i Norge – miljostatus.no) contains the latest information about the state and development of the environment. The website's pages are continually updated, and all information and all data are quality assured twice a year. State of the Environment Norway was developed by the environmental management authorities, and the Norwegian Polar Institute has contributed. The website is aimed primarily at the general public and little of the information it contains has the degree of depth that government agencies often require.

The Norwegian Polar Institute website (www.npolar.no) is the Institute's main platform for disseminating knowledge about the Arctic and the Antarctic to the Norwegian government and the general public. In the past few years, considerable effort has been made

to give the website a format that simplifies access to the current status of knowledge within the Institute's core areas: pollutants, climate and biodiversity. Emphasis has been placed on improving the connections between underlying databases and map services and the textual information provided on the website. The aim is to offer an overall summary of current knowledge within key topics, and provide simple, seamless access to more detailed scientific information. The Norwegian Polar Institute is focused on ensuring sound editorial and scientific structures in developing the website content.

The Norwegian Polar Institute is also in charge of coordinating the **environmental monitoring system MOSJ**. The dissemination platform for this system (www.mosj.npolar) serves to communicate to government agencies the results of the monitoring, so that evaluations can be made and advice given related to attaining the political targets that have been set for environmental developments in the High North.

The Barents Portal (www.barentsportal.com) is the result of a cooperative project implemented under the Joint Norwegian–Russian Commission on Environmental Cooperation. The main purpose of the Barents Portal is to provide a holistic description of the Barents Sea ecosystem, as well as activity and environmental impacts in the area, so as to give decision-makers on both the Norwegian and Russian sides a common point of departure on which to base environmental management decisions and measures related to this area of the ocean.

Antarctic Environments Portal (www.environments.aq) is an initiative led by Antarctica New Zealand, in close cooperation with the Scientific Committee for Antarctic Research (SCAR), where the Norwegian Polar Institute is also a cooperation partner. The purpose of this portal is to act as the link between research and the decision-makers in the Antarctic Treaty system. The portal's aim is to provide brief and targeted summaries of knowledge in areas of primary interest to government agencies. All content presented in the portal undergoes a thorough editorial process with peer reviews of all the texts produced.

Both the Norwegian Polar Institute specifically, and the Fram Centre generally, have a mandate to collect knowledge that is relevant to society. The mission of the Norwegian Polar Institute is to be the key knowledge provider to government agencies as regards the polar regions, and to "*strengthen the knowledge base in areas where the environmental management authorities have a direct management responsibility in the High North and the polar regions*".

There must be a continued focus on ensuring that the knowledge generated at the Fram Centre is prepared and disseminated in a purposeful and accessible manner to those who have requested it, in parallel with scholarly publication of that knowledge. Against this backdrop, developing good, robust, scientifically sound and continually updated web-based dissemination products must be a priority.

Christine F. Solbakken // NILU – Norwegian Institute for Air Research

Computer modelling identifies new environmental contaminants

NORWAY'S NATIONAL ENVIRONMENTAL AGENCIES have a vision of a toxin-free future. That means we need to be able to identify both known and emerging environmental contaminants, which implies a considerable need for research. In addition, we need to learn more about what risks these substances pose for humans and the environment.

A recently completed research project shows that the use of computer modelling can contribute to this work. The research project (Miljø2015) was headed by NILU - the Norwegian Institute for Air Research with funding from the Research Council of Norway, and has been conducted in close collaboration with the universities of Stockholm and Toronto.

Postdoc Ingjerd Sunde Krogseth and senior researcher Knut Breivik. *Photo: NILU*

EVERY SUBSTANCE IS DIFFERENT

"Chemical substances act very differently when they are emitted into the environment, and fortunately many substances disappear rapidly without causing any damage," explains Ingjerd Sunde Krogseth, formerly a PhD candidate and now a postdoctoral researcher at NILU.

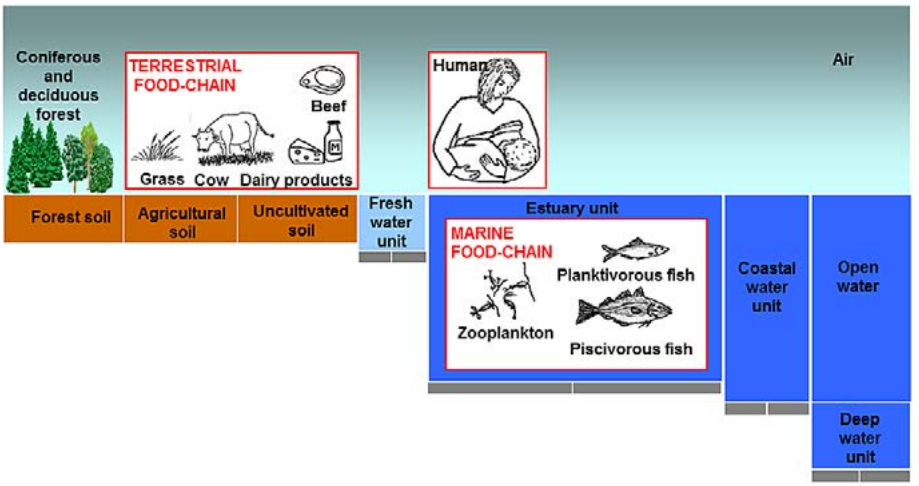
"We are primarily interested in so-called persistent organic pollutants (POPs) and POP-like chemicals. These are substances that remain in the environment and that can enter the food chain, causing harm to animals or people."

"The vision behind our research," continues Knut Breivik, senior researcher at NILU, "is to understand, and to predict, links between sources of environmental contaminants and how humans and the environment are exposed to them. This will allow us to develop the most effective measures to tackle the problem." Breivik has been principal investigator for the project.

"Much of the background to the project is a computer model that we use to simulate how chemical substances act in the environment," explains Breivik, "and in what concentrations we can expect to find them."

KNOWLEDGE GAPS REVEALED

A chemical substance is considered potentially harmful if it is toxic, persistent (breaks down slowly in nature), accumulates in living organisms, and/or can be transported over long distances. If a substance



The CoZMoMAN computer model has been used to understand links between emissions and exposure to organic environmental contaminants.

fulfils several of these criteria, the warning lights start flashing for environmental agencies and researchers.

But potential harm alone is not enough to motivate regulation of a substance. Ultimately, it is all about risk. That means we must also understand the actual exposure - the doses that the environment and humans are exposed to. If exposure levels are so low that the substance has no effect on human health and the environment, there is little cause for alarm, even if one or more of the other hazard criteria are met.
"In order to be able to say something relevant about risk, we have to understand the link between the quantity of emissions and exposure. Without that knowledge, risk is difficult to understand and to manage," Krogseth explains.

The researchers believe they have figured out a way to advance their understanding. They will use computer models to simulate how chemicals act in the environment, and at what concentrations the various substances can be expected. Comparisons between these model results and actual measurements of the chemicals in the environment can be very helpful to identify what we understand - and what we don't understand.

SILOXANES

An example from the project is the work done on siloxanes, a large group of substances frequently used in skin and hair care products, and which are released into the environment in large quantities.

Model simulations suggested that some of these substances are transported via air currents over long distances to the Arctic - and that conclusion was confirmed by actual measurements taken at the Zeppelin Observatory in Svalbard.

"The models can tell us where and when we should take measurements, and can subsequently reproduce observations and give us insight into links between sources and exposure. That's a great help," explains Krogseth.

"It means we don't have to fumble around in the dark, and we have a tool that can reveal causal links between sources and exposure. The environmental agencies need that kind of information to consider whether emissions should be curbed."

TRADE SECRETS MAKE EMISSION ESTIMATES UNCERTAIN

What kinds of substances are being produced, what they are being used for and in what quantities, is usually proprietary information and thus not openly available. Lack of accurate, up-to-date information is a challenge for the researchers, because uncertainty in estimates of how much of any specific substance is being released into the environment ultimately means uncertainty in the results of the research.

"That is an obstacle," says Breivik. "Greater openness would enable us to more effectively identify substances that should be examined more closely, and potentially be regulated."

REVEALS NEW CONTAMINANTS

"But our work isn't complete until we have confirmed through observation that the models are producing reasonable calculations," Breivik adds.

Since the research at both NILU and Stockholm University was already focused on siloxanes, the institutes agreed to test the model by examining 215 siloxane compounds more closely. The model flagged three of them as possible environmental contaminants, even though they had not previously been detected in the environment.

The researchers at Stockholm University developed the necessary analytical methods and obtained samples from the field in both Sweden and Norway. Their measurements established that all three of the predicted environmental contaminants were present in at least one sample - and one substance was detected in all samples.

In many respects, these findings represent a breakthrough for the teamwork that has been put into the project.

"We've shown now that the models are also good enough to help identify new environmental contaminants," says Breivik.

RELEVANT CLIMATE CONDITIONS

Another advantage of the models is that they have been set up to describe Nordic climate and environmental conditions.

"The models must recreate relevant environmental conditions in order to give us realistic and relevant predictions," Breivik continues, referring to the fact that a great deal of the attention surrounding environmental contaminants in Norway has been focused on the elevated concentrations found in humans and the environment in the Arctic. Chemical substances behave very differently in the Arctic and in the tropics, for example, and the computer models must take such features into account.

Breivik and Krogseth are eager to continue working with the models to try to reduce the remaining uncertainties as much as possible. This will improve their understanding of how chemicals behave, and they can use their experience to elucidate the challenges of tomorrow.

"A great deal of hard work remains and there are plenty of problems to tackle," the two researchers admit. "But the fact that the computer models are leading us to new substances, which we can then detect in the environment, inspires us to keep on searching."

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Elisabeth Isaksson, Jean-Charles Gallet, Christina Pedersen and Sebastian Gerland // Norwegian Polar Institute

Looking for black carbon in Svalbard snow and ice

Short-lived pollutants and their effect on climate have received much attention in the political debate during the past decade and black carbon has been a main focus of interest. This article describes research conducted in a place where there is little black carbon – but where it is expected to have strong impact.

Black carbon (BC) is emitted from incomplete combustion of fossil fuel and biomass burning. BC warms up the atmosphere and decreases the amount of incoming solar radiation reflected by snow and ice surfaces, i.e. albedo. Svalbard has few local sources of BC, making it a suitable area for investigating transport of pollutants from lower latitudes. At Zeppelin mountain outside Ny-Ålesund, BC levels in air have been monitored since 2002. Results show an annual variability with the highest concentrations in connection with the arctic haze in March and an overall decreasing trend over time.

Although most BC particles are emitted at lower latitudes, a significant portion is transported to the Arctic by air currents, before being deposited onto snow. Atmospheric models are often used to estimate the air transport capacity of BC and its deposition onto snow. However, these models provide different results because of how they account for different transportation and deposition processes. Therefore, we need to validate these models with field measurements.

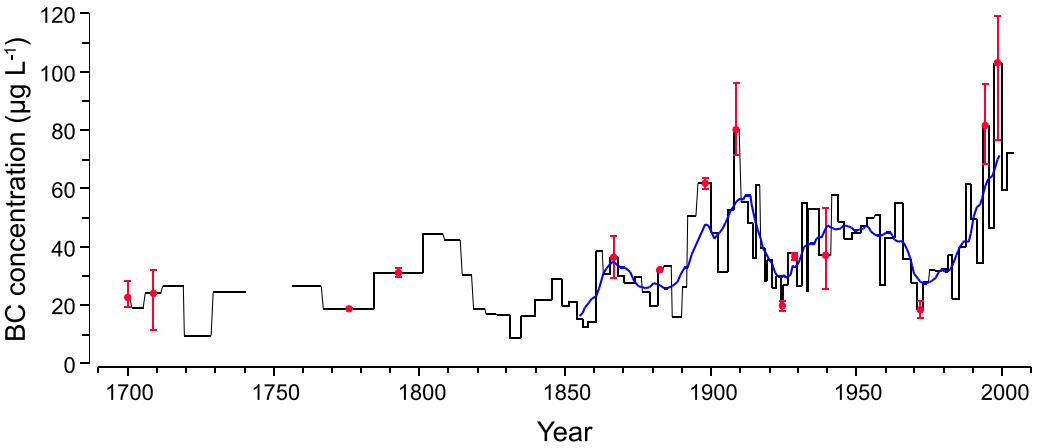
SPATIAL VARIABILITY

The spatial variability in snow samples was determined using the annual snow layer on various glaciers and sea ice in Svalbard during 2008-2010. Results show clear differences in the geographical distribution of BC, with the highest concentrations in eastern Svalbard. We attribute this to a dominance of air transport from polluted areas in Siberia and Eastern Europe. Western Svalbard receives more of its BC from air masses that have travelled over the North Atlantic, in other words, the air is cleaner. Local sources of BC can also play a role: samples from the glacier Linnébreen clearly show the contribution from coal and oil burning in Barentsburg.

TEMPORAL VARIATIONS

Ice cores from glaciers can provide important information on past climate and atmospheric conditions, and are therefore a valuable tool for extending existing data back in time. We analysed BC in an ice core from Holtedahlfonna that was drilled in 2005, covering the time from about 1700 to 2004. These data suggest that BC began to increase after 1850, reaching a peak around 1910. The results are similar to those obtained from ice cores taken in Greenland. However, the ice core from Svalbard suggests that BC increased rapidly between 1970 and 2004, after a temporary low level around 1970. No similar trend can be seen in ice cores from Greenland. Moreover, the increase seems

Ice core drilling and processing in Svalbard.
Photo: Gerit Rotschky



Black carbon (BC) concentrations in the Holtedahlfonna ice core during the last 300 years (black curve: concentrations at sample resolution, blue curve: running 10-year averages). The red dots and error bars indicate average concentration and the absolute errors of samples on which multiple analyses were performed (modified from Ruppel et al. 2014).

to contradict atmospheric measurements indicating an overall downward atmospheric BC trend since 1989 in the Arctic. Possible reasons for this recent increase include flaring in Siberia and modifications in the atmospheric transport capacity. This topic will be investigated further using chemical transport models.

EFFECT OF BC ON THE RADIATIVE BUDGET

Are the BC levels we find in snow and ice on Svalbard sufficient to perturb the radiative budget of snow and ice? A small amount of BC (as little as 10 ppb, or 10^{-9} gram of soot per gram of snow) is theoretically sufficient to decrease the snow albedo by 1%. Since the albedo of pure snow can be as high as 99%, a 1% increase in absorption would double the amount of absorbed energy. When BC is deposited on a snow surface, it increases the amount of energy absorbed and increases the melting rate of snow. And when snow melts, BC tends to stay at the surface, which further increases the melting.

PERSPECTIVES IN A WARMING ARCTIC SYSTEM

The climate of the future is of great concern for humanity. BC is a short lived climate forcer, but its global effect is poorly known. BC warms up the atmosphere, and increases the melting rate of snow and ice - but these are only the direct effects. At low latitudes, BC particles serve as cloud condensation nuclei, modifying cloud cover and distribution - and consequently the amount of precipitation. These are indirect effects, and not only is their magnitude unknown, but also whether they ultimately enhance or diminish climatic forcing. It is therefore of great interest to pursue efforts in understanding the effect of BC particles on climate. Considering that the lifetime of BC particles in the atmosphere is only about a week, decreasing our emissions would have a very fast and beneficial climatic effect.

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Linda Storholm // High North News

Science in the City

When the Fram Centre participated at the science festival "Science in the City", the main objective was research dissemination – sometimes through unorthodox channels – and people who hoped to visit the High North themselves appeared to be paying particularly close attention.

Copenhagen was the host city for the biannual science festival "Science in the City" in June 2014. For one hectic week, Carlsberg's former brewery buildings were a bubbling cauldron of research, knowledge, new experiences, exhibitions and live performances. More than 80 exhibits were on offer in several buildings and areas.

Both the Norwegian University of Science and Technology and the University of Nordland were represented, but the largest Norwegian participant was the Fram Centre. The Centre's "Arctic Knowhow" exhibition focused on disseminating scientific knowledge about the animals and natural environment of the Arctic.

"We have six flagship research programmes, and we chose to focus on the three that we thought would be of greatest interest to the Danish public," explains outreach coordinator Helge M. Markusson.

TOURISTS WANT TO KNOW

Maria Nørhave and Thomas Gamlegård were sitting in the auditorium when Arild Sundfjord and Jakob Grahn gave their talk about the extent and thickness of the arctic ice, and why it is so important for us to know these things.

The couple – she's a teacher and he's a tour guide – both want to know more about the sea ice and how it is being affected the climate.

"In my job as a tour guide, I travel a lot to Norway. I just got back from the North Cape, and I'd like to know something about the place so I can tell my tourist groups about it," explains Gamlegård.

He has visited the glaciers Svartisen and Engabreen several times and says it makes a huge impression when you get so close to the ice that you can see how much it has retreated in the past few years.

"Tourists are interested in knowing more about this," says Gamlegård, "particularly when they're confronted at such close quarters with the issue of melting ice."

The only negative comment the two had about the talk was that it should have been held in Norwegian rather than English.

"They were good at explaining things, but I'd like it to have been in Norwegian," says Nørhave, and declares that, like her husband, she is a big fan of Norway.

WANT TO LEARN SOMETHING

"It seems as though the people who've come to this

event are genuinely interested. People who seek out a science festival are eager to learn something," says Helge M. Markusson.

Keywords here are climate change, fjord, coast, environmental toxins, the Arctic Ocean and melting sea ice. And here knowledge and information are being passed along in many different ways. Two daily lectures, two daily theatrical performances, and an exhibition of photographs taken by scientists in the field – including award-winning photos taken by Audun Rikardsen.

Visitors to the festival have been of all ages. The theatrical performance about environmental toxins in the Arctic was particularly popular with schoolchildren, and each performance attracted 30-40 students. The aim of reaching an international audience has been achieved.

BIGGEST EVENT OUTSIDE NORWAY

"One of the Fram Centre's obligations is to disseminate our research to a broad national and international audience," says Markusson.

The "Science in the City" festival is the biggest event the Fram Centre has participated in outside Norway; it is important to disseminate new knowledge about the sea ice and climate change.

"We can see that Europe's environmental toxins are ending up in the Arctic," explains Markusson. "For example, we can measure the fallout from a Polish forest fire in Svalbard three days after the event. It's important to tell European consumers that their consumption affects the Arctic – that their behaviour helps determine whether or not polar bears have ice to live on, for example."

EXOTIC NORTH

And the questions the visitors pose indicate that the world north of the Arctic Circle is an exotic place for our neighbours to the south.

"They wonder about things like how long it stays dark, how deep the ocean is at the North Pole, what the Northern Lights are like, and how cold it actually gets. For example, they find it incredible that in northern Norway we can see the Northern Lights from our verandahs," smiles Markusson.

The distance between Svalbard and the mainland is also a recurring theme. Many people are fascinated by how far it is between Tromsø and Svalbard.

NORTHERN LIGHTS EVENT

In addition to bringing its research to a wider audience, the Fram Centre has been actively cooperating with businesses in the High North at the festival.

"With excellent assistance from the Danish office of Innovation Norway, we organised a mini-event about the Northern Lights on Tuesday."

Representatives of businesses involved in Northern Lights tourism participated; there was a presentation about the Northern Lights as a geophysical phenomenon, and a reception was held for 40 guests, including 25 Danish journalists.

"Research, business and culture go hand in hand," says Markusson. "We're rather proud of managing to bring that off."

He also has praise for the Norwegian Embassy, which helped to get everything in place.

"Are you planning to take part in similar events in the future?"

"Yes, absolutely. Whether we'll be at the next "Science in the City" I don't know, but we'll definitely be maintaining an international presence."

Trude Borch // Akvaplan-niva

Arctic Frontiers 2015 Climate and Energy

January 2015: After much preparation, the Arctic Frontiers secretariat and Tromsø stood poised to host 1400 delegates for a week of Arctic policy, business and science discussions.

OPENING DIALOGUE

The afternoon of 19 January offers a lot more activity at the Fram Centre than what is normal for a Sunday. The former director of the Norwegian Polar Institute Olav Orheim is arriving. He has been appointed to the task of leading the Opening Dialogue of the 9th Arctic Frontiers conference. It is a very special occasion, not least as His Serene Highness Prince Albert II of Monaco is taking part in the ceremony, sharing his perspectives on the future Arctic.

THE POLICY SECTION

Monday morning and a change of venue. The two-day policy section of Arctic Frontiers is starting up at the UiT The Arctic University of Norway. Liv-Monica Stubholt, director of the Norwegian–Russian Chamber of Commerce, will moderate a day of talks by such dignitaries as Børge Brende, the Norwegian Minister of Foreign Affairs, Robert Papp, US Special Representative for the Arctic and Artur Chilingarov from the Russian Geographical Society. Two parallel breakout sessions follow, entitled "Neighbourly Asymmetry – Norway & Russia" and "Present geopolitical situation – a challenge for Arctic cooperation?" The policy section continues the next day with a report on Sustainable Economic Growth in the North and an armchair talk with Erna Solberg, Prime Minister of Norway, Alexander Stubb, Prime Minister of Finland and Kristina Persson, Sweden's Minister for Strategic Development and Nordic Cooperation. Martin Lidegaard, Minister of Foreign Affairs of the Kingdom of Denmark gives a keynote talk. Two breakout sessions, "From Science to Politics" and "Towards COP 21" (the UN Climate Change Conference) end the day.

THE BUSINESS SECTION

On Tuesday afternoon, Tromsø's brand-new Edge Hotel hosts the most recent addition to the conference structure, Arctic Frontiers Business. The delegates have signed up to learn about drivers for arctic business development, this year with a special focus on Barents Sea oil and gas and arctic mining. A presentation on collaboration for circumpolar innovation by professor Ron Coates from the University of Saksatchewan, is followed by presentations from Aker Solutions, Gassco, Statoil, Rambøll and the mining company Leonhard Nilsen and Sons (LNS). Arctic Frontiers Business ends with a matchmaking event in which businesses can build partnerships across sectors and national borders. Enterprises from Finland make up nearly half of the participants. The Finns are very active in seeking business partnerships and many of them look to Norway.

Arctic Frontiers opening dialogue 2015
Left to right: Jens Ulltveit-Moe, CEO Umoe; HSH Prince Albert II of Monaco; Fran Ulmer, Chair, US Arctic Research Commission; Kjell Giæver, Director Petroarctic

Photo: Pernille Ingebrigtsen/Arctic Frontiers 2015

THE SCIENCE SECTION

We, on the other hand, turn our gaze back towards the University. It is Wednesday morning and Arctic Frontiers Science is about to start. Following the opening plenum the delegates separate into three sessions: “Arctic Climate change – global implications”, “Ecological winners and losers in future Arctic marine ecosystems” and “The Arctic’s role in the global energy supply and security”. All sessions are led by independent science committees and the presentations can be downloaded from the Arctic Frontiers webpage. By lunchtime Friday the organising committee can wrap up a conference week with three sections and more than 40 side events and meetings. In 2016 we invite the delegates back to celebrate the 10th anniversary of Arctic Frontiers, this time focusing on “Industry and Environment”.

WHAT IS ARCTIC FRONTIERS?

The overall aim of the annual conference Arctic Frontiers is to contribute to sustainable development in the Arctic by creating an arena for disseminating updated scientific knowledge to political and industrial decision-makers. To include future generations in this process, the Young Scientist Forum has been an integral part of since the very first conference in 2007. Arctic Frontiers is organised by Akvaplan-niva, and the steering committee includes 20 partners from academia, business and public sector. Arctic Frontiers is the world’s largest conference on arctic issues, contributing to making Tromsø an arctic competence hub. It is held in annually Tromsø in the last week of January and gathers 1400 participants from 35 countries.

See www.arcticfrontiers.com

Helge M. Markusson and Jo Jorem Aarseth // Fram Centre

Fram Awards 2014 to Nahrgang and Strann

Karl-Birger Strann of the Norwegian Institute for Nature Research and Jasmine Nahrgang of UiT The Arctic University of Norway were awarded of the Fram Centre prizes for 2014.

The annual Fram Awards, which render the two awardees 25 000 NOK, a diploma and an artwork, were presented at the Fram Centre's Fram Day on Thursday 13 November 2014. Fram Day is an annual event established with the aim of fostering interdisciplinary cooperation, greater professional and social contact, and to inspire better and broader dissemination of research. A total of 10 individuals from the Fram Centre's member institutions were nominated for the awards.

WINNER OF THE FRAM CENTRE'S RESEARCH AWARD 2014:

Jasmine Nahrgang, Associate Professor,
UiT The Arctic University of Norway

Jasmine Nahrgang is an Associate Professor in the Department of Arctic and Marine Biology, and has carved out a solid name for herself in the research community in the past few years.

"The Fram Centre's Research Award for 2014 goes to a researcher who, taking into account her young age, has over the course of several years produced a very considerable body of scientific research of very high quality, first and foremost through articles published in international scholarly journals. The award winner's research collaboration, nationally and – in particular – internationally, is extremely extensive. In addition she actively disseminates the results of her research at international conferences and in the media. The award winner has an outstanding capacity to attract considerable research funds for her own research from a number of different funding sources. The winner has also demonstrated a great willingness to provide guidance and supervision for students and to take an active part in teaching.

"It is the conclusion of the committee that the award winner perfectly fulfils all the criteria for the Fram Centre's Research Award, and they regard her as an excellent representative of the work that is based on, and carried out within, one of the flagship research programmes pursued in the Fram Centre."

WINNER OF THE FRAM CENTRE'S RESEARCH DISSEMINATION AWARD 2014:

Karl-Birger Strann, Senior Researcher,
Norwegian Institute for Nature Research (NINA)

Strann has worked as a researcher at NINA ever since the institute was established in 1988. His research has focused mainly on wading birds and seabirds. Strann retired on 21 November 2014.

From the awards ceremony on Thursday 13 November. Left to right: Karl-Birger Strann, Norwegian Institute for Nature Research (NINA), Are Johnsen, General Manager of Framsentret AS, Jasmine Nahrgang of UiT The Arctic University of Norway, and Jo Jorem Aarseth, research coordinator at the Fram Centre and secretary for the awards jury.

Photo: Helge M. Markusson, Fram Centre

Throughout his career, Karl-Birger Strann has been known as a disseminator of scientific research who is full of initiative and who has long been a visible presence in the media through talks and lectures and through book publications.

He has shown a particular commitment to conveying his enthusiasm for science to children and young people – something that the jury also considered particularly worthy of mention.

"The Fram Centre's Research Dissemination Award for 2014 goes to a researcher who for many years has disseminated a large body of research results with outstanding skill and across a broad spectrum. The winner is an active and positive disseminator, with a mastery of the traditional channels of communication, through interviews in TV, radio, newspapers, lectures and book publishing, and who himself frequently takes the initiative to bring knowledge to a wider public. In addition, the award winner shows an enthusiasm for, and commitment to, disseminating knowledge to new generations, which often demands an effort over and above what might be expected. The award winner fulfils all the criteria for the Research Dissemination Award.

"The recipient is a very worthy winner of this year's Research Dissemination Award."

Maja Sojtaric // Centre for Arctic Gas Hydrate, Environment and Climate (CAGE), UiT The Arctic University of Norway

Methane seepage from the Arctic Ocean

Methane has been seeping from the seabed off Svalbard for at least 2.7 million years, according to a new study. During this period, there have been at least two major methane emission events.

We worry about greenhouse gas methane. Its lifetime in the atmosphere is much shorter than that of CO_2, but methane has over 20 times greater impact on climate change over a 100-year period.

Sixty percent of the methane in the atmosphere originates from human activities. But methane is a natural gas, and gigatonnes of it are trapped under the ocean floor in the Arctic.

"Our planet leaks methane gas all the time. If you go snorkeling in the Caribbean you can see bubbles rising from the ocean floor. We found the same type of release in a deeper, colder, darker environment, and found out that it has been going on, periodically, for 2.7 million years," says Andreia Plaza Faverola, lead author of the new paper in *Geophysical Research Letters*.

Her group studied Vestnesa Ridge in Fram Strait, where 800-metre gas flares rise from the ocean floor.

"Half of Vestnesa Ridge is showing very active seepage of methane. The other half is not. But there are obvious pockmarks on the inactive half, cavities and dents in the ocean floor that we recognised as old seepage features. We wondered what activates, or deactivates, seepage in this area," says Plaza Faverola. Using seismic methods, she and her colleagues at CAGE have identified two major gas emission events, 1.8 million and 200 000 years ago.

This means something activated and deactivated the emissions several times. Plaza Faverola's paper proposes that relatively minor movement of tectonic plates triggered release of the methane stored under the ocean floor.

"Although Vestnesa Ridge is on a passive margin, it is between two oceanic ridges that are slowly spreading, separating Svalbard from Greenland and opening up the Fram Strait. Even a small mechanical collapse in the sediment can trigger seepage," says Faverola.

Vestnesa hosts a large system of gas hydrates – chunks of frozen gas and water – deep under the ocean floor. Some are concerned that global warming may melt this icy gas and release it into the atmosphere. That is not very likely in this area, according to Andreia Plaza Faverola.

"This is a deep water gas hydrate system, lying in permanently cold waters and under a lot of pressure, which keeps the hydrates stable. The system is not vulnerable to global temperature changes. But under the stable hydrates there is gas that is not frozen. The amount may increase if hydrates melt at the base of the stable zone, or more gas rises from deeper in the sediments. This could increase pressure in the system, and the free gas may escape the seafloor through chimneys. Hydrates would still remain stable in this scenario."

Earth's history shows several short periods of significant increase in temperature, often coinciding with methane peaks in the atmosphere. Scientists are still debating what caused this methane release.

"One hypothesis is that massive gas release from volcanoes or ocean sediments may have influenced global climate. We know that a lot of methane is now being released from the ocean floor. What we need to find out is if it reaches the atmosphere, or if it *ever* did."

Historical methane release events like the ones in the Vestnesa Ridge provide useful information for climate modelling. Knowing if these events recur, and identifying what causes them, may help us predict how methane from the oceans will influence future climate.

FURTHER READING:

Plaza Faverola A, Bünz S, Johnson JE, Chand S, Knies J, Mienert J, Franek P (2015). Role of tectonic stress in seepage evolution along the gas hydrate-charged Vestnesa Ridge, Fram Strait. Geophysical Research Letters. DOI: 10.1002/2014GL062474

Projects in the Fram Centre Flagships for 2014

Effects of climate change on sea and coastal ecology in the north (Fjord and Coast)

Physical-biological coupling: Oceanography and habitat use by predators and their prey

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Impact of harbour seal predation on Tana salmon and Tana salmon fishery	Martin Svenning	NINA, NIKU, IMR, TRFM	martin.svenning@nina.no
weShare – Ecological and commercial implications of extreme winter arrivals of herring and whales into North-Norwegian fjord systems	Martin Biuw	ApN, NPI, UiT, NORUT, Lkarts, UStA	mab@akvaplan.niva.no
How do a dominant predator and climate shape fish biodiversity over space and time in large marine ecosystems?	Kari Ellingsen	NINA, UiT, IMR, PINRO, BedIn, MU	Kari.Ellingsen@nina.no
Drift of fish larvae, fish-stock interactions and their effect on seabird dynamics	Kjell Einar Erikstad	NINA, IMR, NTNU, CNRS, AU	kjell.e.erikstad@nina.no
Seabird habitat use and migration strategies	Børge Moe	NINA, UNIS, NTNU, NILU, UiT, CNRS, UG, AU, LU, BAS, IMARES, AARI	borge.moe@nina.no
A coastal, ice-associated arctic whale in a changing climate	Christian Lydersen	NPI, UiT, VI, UW	christian.lydersen@npolar.no

Structure, function and change in arctic and boreal fjord ecosystems

Recovery of coastal kelp ecosystems – driven by climate change or predators	Hartvig Christie	NIVA, UiT, UM	hartvig.christie@niva.no
Effects of oceanic inflow and glacial runoff on fjord circulation in Kongsfjorden, Svalbard	Arild Sundfjord	NPI, IMR, UNIS	arild.sundfjord@npolar.no
Life on the edge – blue mussels in Svalbard	Jørgen Berge	UiT, UNIS, ApN, AU, IOPAS, SAMS	jorgen.berge@uit.no
Kongsfjorden Ecosystem – new views after more than a decade of research	Haakon Hop	NPI	haakon.hop@npolar.no
Direct age determination in crustaceans	Jan Sundet	IMR, UiT, ApN, BC, UNB	jan.sundet@imr.no
Trophic interactions in pelagic ecosystems	Tove M. Gabrielsen	UNIS, ApN, UiT	tove.gabrielsen@unis.no
Pelagic ecosystems in ice-covered and ice-free fjords under climate change	Claudia Halsband	ApN, UiT, UNIS	clh@akvaplan.niva.no

Outreach

Fjord and Coast-2011-2014: Synthesis workshop	Arne Bjørge Paul Renaud	IMR, ApN	arne.bjorge@imr.no pr@akvaplan.niva.no

Sea ice in the Arctic Ocean, Technology and Systems of Agreements

Sea ice, ecosystems and models

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
CASPER: Characterization of arctic sea ice properties from remote sensing observations	Torbjørn Eltoft	UiT, NPI, NORUT, MET	torbjorn.eltoft@uit.no
SOLICE: Developing modelling tools to understand the role of solar radiation to sea ice mass balance in a seasonally ice covered Arctic	Mats Granskog	NPI, MET, UiT, ApN, FMI, CRREL, AWI	mats.granskog@npolar.no
ATWAIN: Long-term variability and trends in the Atlantic water inflow region	Vladimir Pavlov	NPI, IMR, UNIS, UiT, IOPAS	vladimir.pavlov@npolar.no
ModOIE: Modelling of ice, ocean and ecology of the Arctic Ocean	Ole-Anders Nøst	ApN, IMR, NPI, SINTEF, MET	oan@akvaplan.niva.no
ArctisMod: Ecosystem modelling of the Arctic Ocean around Svalbard	Pedro Duarte	NPI, ApN, NIVA, UiT	pedro.duarte@npolar.no

Driving forces and development of new industry

Key factors for increased use of the Northern Shipping Route	Eirik Mikkelsen	NORUT, FNI, ApN, Capia, UAF	Eirik.Mikkelsen@norut.no

Regimes for sustainable management

A-LEX: Regulating Arctic Shipping–Political, technological and environmental challenges	Tore Henriksen	UiT, MarinTek, ApN, UU SMU, ILC, MIR, VUB, DU	tore.henriksen@uit.no

Ocean acidification and ecosystem effects in northern waters (Ocean acidification)

Understanding the physical and chemical mechanisms controlling ocean acidification in arctic waters – past, present and future

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Establishing the current status of Ocean Acidification in the Norwegian Arctic – OAstate (OA^{state})	Agneta Fransson Richard Bellerby	NPI, NIVA, IMR	agneta.fransson@npolar.no richard.bellerby@niva.no
The role of Sea Ice processes on Calcium CArbonate saturation levels – SICCA	Agneta Fransson Melissa Chierici	NPI, IMR, NIVA	agneta.fransson@npolar.no Melissa.Chierici@imr.no

Ocean acidification effects on key components of the arctic marine ecosystem

Effects of OA and temperature on arctic vs. boreal zooplankton species and populations	Haakon Hop Howard Browman	NPI, IMR, ApN	haakon.hop@npolar.no howardb@imr.no
Effects of ocean acidification on the reproduction of the reef building cold water coral *Lophelia pertusa*	Johanna Järnegren	NINA, NTNU	johanna.jarnegren@nina.no

Socio-economics of ocean acidification

Economic value and ocean acidification	Eirik Mikkelsen	NORUT, UiT, NIVA	Eirik.Mikkelsen@norut.no

Modelling

Arctic Ocean acidification modelling	Richard Bellerby	NIVA, IMR, NPI, ApN	richard.bellerby@niva.no

Effects of climate change on terrestrial ecosystems, landscapes, society and indigenous peoples (Terrestrial)

Vegetation state change and herbivore management

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
NCoE-Tundra: Herbivore effects on tundra overgrowth, management and environmental gains	Jane Uhd Jepsen	NINA, UiT	jane.jepsen@nina.no
KLIMAVEG: Long term vegetation change in alpine areas in Northern Norway and Poland – relation to climate and grazing	Jutta Kapfer	NFLI, UiT, UOu	jutta.kapfer@skogoglandskap.no
NORKIND: Groundwater associated vegetation in North-Norway	Jutta Kapfer	NFLI, ApN, NGU	jutta.kapfer@skogoglandskap.no
ECOTONE: Aerial observations of structural changes in vegetation – effects of grazing and climate on vegetation and cultural heritage	Jane Uhd Jepsen	NINA, NIKU, UiT	jane.jepsen@nina.no

Ecosystem effects of extreme climate events and changing seasons

WINNIT – effects of extreme weather and long distance pollution on plant societies	Jarle W. Bjerke	NINA, Bioforsk, UiT	jarle.werner.bjerke@nina.no
EWWA: Winter climate and effects of extreme warm weather on vegetation in northern ecosystems	Jarle W. Bjerke	NINA, Norut, Bioforsk, UiT	jarle.werner.bjerke@nina.no
Climate changes and archaeological deposits	Elin R. Myrvoll	NIKU, Bioforsk, UiT	elin.myrvoll@niku.no
FINEGRASS: Effect of climate extremes on inland production of grass in North-Norway	Gregory Taff	NFLI, Bioforsk, NINA	gta@skogoglandskap.no

Capacity for adaptation in indigenous people and local societies

Historical use of landscape: Sami use of the landscape in Sápmi (outreach)	Stine Barlindhaug	NIKU	stine.barlindhaug@niku.no

Adaptive management of ecosystem services

Geese beyond borders: Effects of grazing geese on pasture and tundra	Ingunn Tombre	NINA, NIKU, NORUT	ingunn.tombre@nina.no
Goose grazing: Experimental study of grazing effects of geese	Ingunn Tombre	NINA, Bioforsk, NIKU, ASMH	ingunn.tombre@nina.no
Harvest of arctic resident species	Eva Fuglei	NPI, NINA, UiT, HUC	eva.fuglei@npolar.no

Observation systems for climate effects

COAT: Climate-ecological-Observatory-for- Arctic-Tundra	Rolf Ims	UiT, NINA, NPI, UNIS, MET	rolf.ims@uit.no

General projects across the flagship

Ottar – the Varanger Peninsula (outreach)	Ingrid Jensvoll	UiT, NINA, NPI, NORUT, SPN, MET	ingrid.jensvoll@uit.no
Efficient technology: Composition of plants by use of near infra-red spectroscopy	Kari Anne Bråthen	UiT, Bioforsk	kari.brathen@uit.no

Hazardous substances – effects on ecosystems and human health (Hazardous substances)

Human health and society

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Human health effects of contaminants	Torkjel Sandanger	UiT, NILU	Torkjel.Sandanger@nilu.no / torkjel.sandanger@uit.no

Climate change impact and new contaminants

COPOL – Methylmercury in arctic marine food webs	Anders Ruus	ApN/NIVA, NPI, NILU, SINTEF	anders.ruus@niva.no
COPOL II - Importance of primary and secondary sources for POP-concentrations in Kongsfjorden	Geir W. Gabrielsen	APN/NIVA, NPI, NILU	gabrielsen@npolar.no
Influence of pollution and climate variation in rivers and coastal waters indicated by fresh-water and marine bivalves (Kolarctic)	Michael Carroll	ApN/NIVA, Bioforsk, NINA	michael.carroll@akvaplan.niva.no
Emission, exposure and residence times of cyclic siloxanes in Tromsøysund	Nicholas Warner	NILU, ApN/NIVA	Nicholas.Warner@nilu.no
Uptake and trophic magnification of organophosphorus flame retardants in arctic lake ecosystems	Anita Evenset	ApN/NIVA, NPI, NILU, UiT	Anita.Evenset@akvaplan.niva.no

Environmental contaminants in a multi-stress perspective

Multi-stress relationships in seabird populations: interactions between natural stressors and environmental contaminants	Jan O. Bustnes	NINA, NPI, NVH, ApN, NILU	Jan.Bustnes@nina.no
Effects of contaminant exposure on energetics	Heli Routti	NPI, NILU, UiT, NVH, SINTEF	heli.routti@npolar.no
Impacts of environmental contaminants and natural stressors on northern raptors	Jan O. Bustnes	NINA, NILU, UiT	Jan.Bustnes@nina.no
Microplastics in arctic marine food chains; biological uptake pathways and socio-economic consequences	Claudia Halsband Dorte Herzke	ApN/NIVA, NILU, NINA, NORUT, NPI, UNIS, UiT	claudia.halsband@akvaplan.niva.no dhe@nilu.no
Is the arctic charr population in Lake Ellasjøen, Bjørnøya, affected by chronic exposure to contaminants?	Anita Evenset	ApN/NIVA, NILU, UiT	Anita.Evenset@akvaplan.niva.no

Pollution from petroleum activities and shipping in the north – Effects on arctic ecosystems and communities

The combined effects of radionuclides, metals and organic contaminants in produced water on early life stages of *Calanus finmarchicus*	Louise K. Jensen	NRPA, UiT, NIVA, SINTEF	louise.kiel.jensen@nrpa.no

Risk communication and participatory governance on local, national and international level

Contaminants, food and health security in border regions	Eldbjørg Heimstad	NILU, NORUT, UiT, ApN, NRPA	esh@nilu.no
Heavy metal crabs	Anita Evenset Helena Falk	ApN, NORUT, NILU	Anita.Evenset@akvaplan.niva.no ahf@akvaplan.niva.no

Environmental impacts of industrial activity in the north (MIKON)

Knowledge basis for ecosystem based management

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Advancing environmental risk assessment in the Arctic	Cynthia Juyne Beegle-Krause	SINTEF, NPI, NINA, UiT	CJ.Beegle-Krause@sintef.no
Effects on benthic ecosystems of bottom trawling	Ellen Øseth	APN/NIVA, NPI, NILU	oseth@npolar.no
Ecosystem vulnerability assessment of demersal resources in the Barents Sea	Edda Johannesen Raul Primicerio	IMR, UiT	Edda.johannesen@imr.no raul.primicerio@uit.no

Consequences for organisms and ecosystems

Anthropogenic noise detection using passive acoustic monitoring (PAM) devices in the northern Barents Sea	Kit Kovacs	NPI, UiT	kit.kovacs@npolar.no
Biological effects of the Skjervøy diesel oil spill – a sub-Arctic case study	Kjetil Sagerup	ApN, UiT	kjetil.sagerup@akvaplan.niva.no
GreenAcid-Bile acid analysis of polar cod in connection to the NFR-funded Polarisation project	Jasmine Nahrgang	UiT, UNIS, Unilab	jasmine.m.nahrgang@uit.no
FIMITA – Fate and Impact of MIne TAilings on marine Arctic ecosystems	Hilde C. Trannum	NIVA, ApN, NGU	hilde.trannum@niva.no
Salmon farms as a source of emerging and legacy contaminants in wild fish	Jan Ove Bustnes	NINA, NILU, IMR	Jan.Bustnes@nina.no
CASE – Current Arctic Shipping and the Environment	Stig B. Dalsøren	CICERO, NORUT, SINTEF, Kystverket	stig.dalsoren@cicero.oslo.no
Spatiotemporal distribution of salmon lice in Northern Norwegian fjords	Pål Arne Bjørn	IMR, UiT, NINA	paalabj@IMR.no
Risk assessments of marine birds to oil spills: Developing new methods based on tracking technology and oil drift models	Kjell Einar Erikstad	NINA, SINTEF, IMR, NPI	kjell.e.erikstad@nina.no
Toxicity and fate of black carbon and associated contaminants in Arctic marine ecosystems	Maria Granberg	NPI, ApN, UiT	Maria.Granberg@npolar.no

Consequences for cultural heritage and society

MESAT: Development of methods based on satellites – mapping cultural heritage sites	Elin Rose Myrvoll	NIKU, NINA	elin.myrvoll@niku.no
CULRES-Remote sensing: Mapping and monitoring cultural heritage sites and environments in the Svalbard Archipelago	Stine Barlindhaug	NIKU, NINA	stine.barlindhaug@niku.no
RippEffect – Ripple environmental effects of mining in northern areas	Vera Helene Hausner	UiT, NINA	vera.hausner@uit.no
Reindeer husbandry and development of industry – evaluation of consequences	Jan Åge Riseth	NORUT, NINA	Jan.Age.Riseth@norut.no
The consequences of aquaculture for ecosystem services and societies in the north	Bent Dreyer	Nofima, UiT, IMR	bent.dreyer@nofima.no

ABBREVIATIONS

AARI: Arctic and Antarctic Research Institute; **ApN:** Akvaplan-niva Inc.; **ASMH:** Agricultural Services – Midtre Hålogaland; **AU:** Aarhus University; **AWI:** Alfred Wegener Institute; **BAS:** British Antarctic Survey; **BC:** Bates College; **BedIn:** Bedford Institute; **Bioforsk:** Norwegian Institute for Agricultural and Environmental Research; **CICERO:** Center for International Climate and Environmental Research; **CNRS:** The Centre National de la Recherche Scientifique; **CRRL:** Control/Robotics Research Laboratory (NYU Polytechnic School of Engineering); **DU:** Dalhousie University; **FMI:** Finnish Meteorological Institute; **FNI:** Fridtjof Nansen Institute; **HiFi:** Finnmark University College; **HUC:** Hedmark University College; **ILC:** Institute of Legislation and Comparative Law under the Government of the Russian Federation; **IMARES:** Institute for Marine Resources & Ecosystem Studies; **IMR:** Institute of Marine Research; **IOPAS:** Institute of Oceanology, Polish Academy of Sciences; **KSS:** Kongsberg Satellite Services; **LU:** Laval University; **MarinTek:** The Norwegian Marine Technology Research Institute; **MET:** The Norwegian Meteorological Institute; **MIR:** Moscow State Institute of International Relations; **MU:** Massey University; **NFLI:** The Norwegian Forest and Landscape Institute, **NGU:** Geological Survey of Norway; **NINA:** Norwegian Institute for Nature Research; **NIKU:** The Norwegian Institute for Cultural Heritage Research; **NILU:** Norwegian Institute for Air Research; **NIVA:** Norwegian Institute for Water Research; **Nofima:** The Norwegian Institute of Food, Fisheries and Aquaculture Research; **NORUT:** Northern Research Institute; **NPI:** Norwegian Polar Institute; **NRPA:** Norwegian Radiation Protection Authority; **NTNU:** Norwegian University of Science and Technology; **NVH:** Norwegian School of Veterinary Science; **SAMS:** Scottish Association for Marine Science; **SINTEF:** The Company for Industrial and Technological Research; **SMU:** State Maritime University; **SPN:** Sami Parliament of Norway; **TRFM:** Tana River Fisheries Management; **UAF:** University of Alaska Fairbanks; **UNIS:** The University Centre in Svalbard; **UG:** University of Groningen; **UNB:** University of New Brunswick; **UOu:** University of Oulu; **UM:** University of Maine; **UStA:** University of St. Andrews; **UiT:** UiT The Arctic University of Norway; **UW:** University of Windsor; **UU:** Utrecht University; **VI:** Norwegian Veterinary Institute; **VUB:** Vrije University Brussels

Recent doctorates

Sarah M. P. Berben

A Holocene palaeoceanographic multi-proxy study on the variability of Atlantic water inflow and sea ice distribution along the pathway of Atlantic water

The objective of this project was to quantify sea water temperature and salinity in the Holocene, reconstruct the extent of sea ice, and analyse the driving forces behind variations in Atlantic Water inflow and sea ice distribution. The analyses were based on planktic foraminifera, oxygen and carbon isotope ratios, magnesium/calcium ratios and biomarkers for sea ice and phytoplankton. The study contributes to elucidating how interactions between atmosphere, sea and ice influence the climate system.

Link to the thesis: http://hdl.handle.net/10037/6801

UiT The Arctic University of Norway
Faculty of Science and Technology
Department of Geology

14 October 2014

Eivind Hestvik Brækkan

Why do prices change? An analysis of supply and demand shifts and price impacts in the farmed salmon market

Price changes in any market are essentially due to shifts in supply relative to demand. In a global market there can be several simultaneous supply and demand shifts in different geographical locations, all affecting prices to different extents. This dissertation focuses on procedures for measuring such shifts and their relative effects on prices by looking at the global market for farmed salmon in the period between 2002 and 2011. Farmed salmon is a relatively homogeneous, globally traded product whose market size has burgeoned over the last 30 years. The first study showed that demand varies considerably between years and regions and apparently does not follow the smooth trend usually assumed in empirical demand analysis. The second study determined the size of annual regional supply and demand shifts from exporting and importing regions, along with their impact on prices. These shifts – as well as prices – were found to vary substantially both between regions and within regions over time. The third study disentangled the impacts of income growth and changes in the price of alternative products from the total shift in demand. Results indicate that demand shifts due to unknown factors account for a large portion of total demand growth in all salmon-consuming regions.

Link to the thesis: http://hdl.handle.net/10037/6539

UiT The Arctic University of Norway
Faculty of Biosciences, Fisheries and Economics
School of Business and Economics

1 September 2014

Signe Veierud Busch

Third state involvement in the context of establishing the outer limits of the continental shelf

All coastal states have an inherent right to the continental shelf extending beyond their territorial sea. The outer limit of the continental shelf is at least 200 nautical miles from the coastal states' baselines, and the coastal state enjoys sovereign rights to explore and exploit its natural resources. However, as the continental margin extends beyond 200 nautical miles, the coastal state can establish an extended continental shelf. To do this, the coastal state must submit information to the Commission on the Limits of the Continental Shelf, which makes recommendations to the coastal states on matters related to the establishment of the outer limits of their continental shelf. On the basis of

these recommendations the coastal state shall establish the limits of the shelf, and the outer limits shall be final and binding. This thesis examines the possibility that disputes will arise in this context and discusses how these disputes can be settled in accordance with the Law of the Sea Convention and international customary law. It also discusses the possibility of resolving such dispute in existing judicial forums, as well as the roles of both nations and non-sovereign actors.

UiT The Arctic University of Norway
Faculty of Law
K. G. Jebsen Centre for the Law of the Sea

2 September 2014

Terje Ellingsen

Immune responses in Atlantic cod - with emphasis on antibody responses to bacterial and model antigens

The Atlantic cod has a relatively weak immune response to several pathogenic bacteria and it also lacks several important molecules required to generate antibodies against proteins. Improved insight into the immune response in cod is crucial both for development of vaccines and to understand an "atypical" immune system. This thesis examined cod immune responses to various bacteria and types of antigens. Individual cod displayed widely different antibody responses to *Vibrio anguillarum* and *Aeromonas salmonicida*, whereas all individuals responded well to *Francisella noatunensis*. This latter response was directed against the bacterial lipopolysaccharide. Francisellosis turned out to be transmitted horizontally through the water. Cytokines interleukin-1-beta and interferon-gamma were upregulated from days 15 to 60 of infection. Interleukin 10 was upregulated after 60 days, which suggests that this cytokine has a regulatory effect. The antibody responses to various types of antigens were generally weak, but in some individuals there was an immune response to protein.

UiT The Arctic University of Norway
Faculty of Biosciences, Fisheries and Economics
Norwegian College of Fisheries Science

21 March 2014

Anne Karine Halse

Long-range atmospheric transport and deposition of organic pollutants (POPs) in northwestern Europe

The thesis focuses on persistent organic pollutant (POPs) regulated by international agreements. POPs are toxic compounds, semi-volatile and persistent in both air and other environmental media, and can undergo long-range atmospheric transport to locations (e.g. the Arctic), far away from any point sources. A passive air sampling technique, active air samplers (AAS), and an atmospheric transport model (FLEXPART) were used to analyse the distribution of legacy POPs. Data from 86 stations in 34 countries revealed that legacy POP distribution largely reflects historic and contemporary source regions in Europe. Some Norwegian coastal zones are strongly influenced by local emissions of regulated POPs. In addition, a model-based forecast system was developed and evaluated. The occurrence and distribution of "newly regulated" POPs in soil were also examined. Levels of chlorinated paraffins were high close to source regions. Endosulfans often peaked in precipitation - rich areas, and pentachlorobenzene correlated well with black carbon. Combustion is believed to be a key source.

Link to the thesis:
http://brage.bibsys.no/xmlui/handle/11250/276371

Norwegian University of Life Sciences
Faculty of Veterinary Medicine and Biosciences
Department of Chemistry, Biotechnology and Food Science

Joint supervision with NILU – Norwegian Institute of Air Research

16 December 2014

Jeffrey Morgan Holmes

The Protonics project: distributed observations of auroral dayside Doppler-shifted hydrogen emissions

The Protonics project is an effort to further understand the spatio-temporal dynamics of dayside auroral hydrogen emissions. Spectrometers were deployed to Longyearbyen

and Ny-Ålesund. Measured hydrogen Doppler profiles were analysed via a Monte Carlo model of proton precipitation, giving an estimate of characteristic energy of the precipitating proton/hydrogen population. The difference in energy found between the two stations is interpreted as an ionospheric signature of magnetic merging near the magnetopause. The project also investigated the relative occurrence of electron and proton aurora under the influence of solar wind shocks across the boreal auroral zone. To this end, data from meridian scanning photometers in Canada, Greenland and Svalbard were combined and compared with large-scale UV auroral images from the Polar spacecraft. Significant effort went into ensuring that the ground-based instruments were correctly calibrated for wavelength and intensity; both calibration methods are discussed, along with a scheme for intensity calibration of the colours detected by inexpensive digital cameras.

Link to the thesis: http://urn.nb.no/URN:NBN:no-45651

University of Oslo
Faculty of Mathematics and Natural Sciences
Department of Physics

Joint supervision with the Department of Arctic Geophysics, University Centre in Svalbard

29 August 2014

Diane Elisabeth Groot

Paleoceanography and climate of the NE North Atlantic during the Holocene

This thesis aimed to enhance our understanding of oceanographic variability in the Nordic seas over the past 11 000 years. These seas are a key area within the Atlantic meridional overturning circulation, which helps maintain the mild climate of northwestern Europe by transporting heat from south to north. This process also plays an important role in global heat distribution. Sediment cores from key locations in Nordic seas were retrieved and microfossils in them analysed to reconstruct characteristic of the water masses. The results showed that warm Atlantic Water has flowed into the western Barents Sea continuously for the past 11 000 years. The strength of the inflow has varied, however. High-resolution records covering the past 3 000 years show the temperature variability in Atlantic Water. They also show that the recent warming trend is unprecedented in that time period.
There is also reason to believe that deep water convection has changed in the last century.

Link to the thesis: http://hdl.handle.net/10037/6744

UiT The Arctic University of Norway
Faculty of Science and Technology
Department of Geology

26 September 2014

Kine Østnes Hanssen

Isolation and characterisation of bioactive secondary metabolites from Arctic, marine organisms

Nature is an important source of biologically active molecules that can be developed into pharmaceuticals. Marine bioprospecting alone has generated three novel drugs in recent years, which motivates continued search for promising substances. In this thesis, extracts from Arctic marine organisms were screened for bioactivity. Active extracts were examined for previously unknown active molecules with high-resolution mass spectrometry and candidate molecules isolated with mass guided fractionation. This led to isolation of ianthelline, from the sponge *Stryphnus fortis*, and two dipeptides (breitfussin A and B) from the hydrozoa *Thuiaria breitfussi*. Ianthelline showed potential both as an anticancer agent, where it acted by inhibiting cell replication and enzyme activity, and to counteract biofouling, by inhibiting growth of bacteria and settlement of barnacle larva. Breitfussin A and B were suspected to be previously undescribed compounds. Several advanced techniques were used to elucidate their structure, among them atomic force microscopy, which has not previously been used for structural characterisation of a novel natural product.

Link to the thesis: http://hdl.handle.net/10037/7017

UiT The Arctic University of Norway
Faculty of Biosciences, Fisheries and Economics
Norwegian College of Fisheries Science

9 December 2014

Johanna E. H. Hovinen

Foraging, reproduction and survival of the zooplanktivorous seabird little auk (*Alle alle*) in the Arctic in relation to climatic and environmental variability

In order to assess the effects of predicted future climate change on seabird populations, it is important to understand how life-history traits, such as reproduction and survival, are influenced by climatic and environmental variability. The aim was to assess the effects of climatic and environmental variability on foraging, reproduction and survival of the little auk (*Alle alle*), based on data from colonies on Bjørnøya and West-Spitsbergen. Adults preferred to forage in cold water masses at the shelf-sea area. The number of good quality prey items delivered daily to a chick correlated negatively with ocean temperature, and both chick fledging success and adult survival were higher when ocean temperature was lower. The higher fledging and survival probabilities were likely due to higher availability of arctic zooplankton. Replacement of arctic zooplankton with smaller Atlantic species of lower food quality may result in decreases in little auk populations. This may influence the dynamics of the arctic food web, in which little auks play an important role.

Link to the thesis: http://hdl.handle.net/10037/6385

UiT The Arctic University of Norway
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

Joint supervision with the Norwegian Polar Institute and the University Centre in Svalbard

23 June 2014

Harald Dag Jølle

Nansen. Oppdageren / Innledning til en historiefaglig biografi [Nansen. The Discoverer / Introduction to a historic biography]

This thesis is the first volume of a biography of Fridtjof Nansen. This is the first biography that integrates Nansen the scientist into the description of Nansen the polar and national hero. It presents the scientific disciplines Nansen was most deeply involved in, and describes how his research contributed to new insight into the polar regions and physical oceanography – knowledge that helped lay the foundation for modern climatology. Nansen's character emerges as that of an intellectual who tried to transfer his scientific world-view to practical rules of conduct, a romantic who struggled to grasp the meaning of life, a modern Darwinist who criticised imperialism, a political liberal whose relationship with the parliamentary system was sometimes strained. This is the story of a strong man with strong opinions, strong feelings, arching ambitions, and a solid belief in his own capacity. This is the story of the contradiction that is Nansen – Nansen as you have never met him before.

UiT The Arctic University of Norway
Faculty of Humanities, Social Sciences and Education
Department of History and Religious Studies

Jølle is employed at the Norwegian Polar Institute

14 February 2014

Arve Lynghammar

Chondrichthyan fishes in the Arctic Ocean and adjacent seas – do we know our species?

The basal prerequisite for managing species and understanding ecosystems is correct species and population identification. This thesis gives an overview of chondrichthyan fishes (sharks, skates, rays and chimaeras), recorded in the Arctic Ocean and adjacent seas. A total of 49 species were found to occur, and the most specious regions were the Bering Sea, the Norwegian Sea and the Barents Sea, also known as the Arctic Gateways. The Bering Strait is an effective zoogeographic barrier, separating the Pacific from the Atlantic species. Species complexes of skates are known to occur, and the group is commonly lumped as "Skates & Rays" in fishery statistics or in scientific publications. By use of genetic methods (DNA barcoding), the skate species reported from the northern Northeast Atlantic were investigated. A total of 12 species were found to occur in the area, and three of those were new for the region. Skates are commonly encountered in the Northeast Atlantic, but about 95% are the small *Amblyraja radiata*. Some of the larger skate species are considered threatened.

Link to the thesis: http://hdl.handle.net/10037/6785

UiT The Arctic University of Norway
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

Joint supervision with the Norwegian Polar Institute and the Institute of Marine Research

31 October 2014

Sanna Majaneva

Understanding the biodiversity and ecological importance of ctenophores. Lessons from Arctic and Baltic *Mertensia ovum*

Comb jellies are among the most difficult pelagic animals to study. This means that their diversity is underestimated and their role in the ecosystem is often misunderstood. Gelatinous zooplankton can be abundant in marine ecosystems and have important effects at both high and low levels in the food chain. This thesis attempts to shed some much-needed light on these creatures. Their biodiversity was studied using both morphological and molecular methods of identification and their ecological roles were studied with a battery of techniques including sampling, laboratory experiments, and gut content analysis. A particular focus was on *Mertensia ovum*, a species of comb jelly found both in the Baltic and in the Arctic. In the Arctic, *M. ovum* was shown to predate voraciously on copepods. Conversely, individuals in the Baltic population are considerably smaller and prey mainly on microplankton. This illustrates the risk of generalising and extrapolating ecological traits such as diet and foraging behaviour from one population to another. To draw correct conclusions, careful field studies are required.

Link to the thesis:
https://helda.helsinki.fi/handle/10138/43182

University of Helsinki, Finland
Faculty of Biological and Environmental Sciences,
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Joint supervision with the Department of Arctic Biology, University Centre in Svalbard, and the Department of Ecology, Environment and Plant Sciences, Stockholm University

11 April 2014

Therese Haugdahl Nøst

Understanding temporality in human concentrations of organic contaminants: Considering human concentrations over time and through life in perspective of historic production and use

The overall aim of this thesis was to enhance our understanding of how concentrations of persistent organic pollutants (POPs) have changed in individuals over time. Five repeated measurements between 1979 and 2007 from 54 men in the Tromsø Study were used. Concentrations of most PCBs and organochlorine pesticides decreased from 1979 or 1986 whereas concentrations of some perfluoroalkylic acids increased from 1979 to 2001 and decreased to 2007. The time trends of POP concentrations generally display a strong link to the compounds' concentrations in the environment and production. Clearly, discontinued production and use of some POPs have led to decreasing concentrations in humans. The measured concentrations of PCBs agreed well with concentrations predicted by emission-based exposure modelling on both group and individual basis in men from the Tromsø Study and in two female study groups. This demonstrates the potential of mechanistic modelling as a useful tool in human biomonitoring and effect studies.

UiT The Arctic University of Norway
Faculty of Health Sciences
Institute of Community Medicine

Joint supervision with NILU – the Norwegian Institute of Air Research, and the University Hospital of North Norway

25 June 2014

Tom Arne Rydningen

Sedimentary processes, late Cenozoic evolution and sediment yield on the continental margin offshore Troms, northern Norway

The continental margin outside the islands of Kvaløya, Senja and Andøya in Troms contains glacigenic sediment up to 1000 metres thick. These sediments were deposited over a period of three million years and originate from fjords and valleys in Troms. The deposits were mapped with the aid of bathymetric data and seismic profiles, which reveal the depth and shape of the seabed and the underlying strata. The research shows that during the early phase of deposition, the glaciers were mainly in alpine terrain on land. At about 1.5 million years before present, the deposition pattern shifts to one suggesting larger glaciers that extended as far at 50 kilometres out from the coastline in cycles lasting 40 000 to 100 000 years. The estimated sedimentation and erosion rates can be compared with results from other parts of the Norwegian continental margin and can improve our understanding of the ice ages and how glaciers shaped the continental margin in this area.

Link to the thesis: http://hdl.handle.net/10037/6437

UiT The Arctic University of Norway
Faculty of Science and Technology
Department of Geology

19 June 2014

Teppo Rämä

Diversity of marine wood-inhabiting fungi in North Norway

Fungi that grow in seawater – marine fungi – can be found everywhere in the seas, including the cold waters off the coast of North Norway. Their tiny fruiting bodies are hardly visible to the naked eye and they have rarely been studied in the Arctic. This doctoral project set out to gather more information on the diversity of marine fungi in driftwood along the shores of North Norway and Svalbard. A combination of micromorphological and molecular genetic techniques revealed 925 potential species on just 50 pieces of driftwood. Of these species, 16 turned out to be new to Norway and one was new to science. Both marine and terrestrial fungi were found. The latter can spread from the Siberian taiga, where most of the driftwood originates, to the Norwegian coast. Many of the fungi are known to produce bioactive molecules, some with medical uses. The material gathered in this study may yield other potentially interesting bioactive substances. Some of the fungi identified are known to be harmful fish parasites. These may pose a threat to Norway's growing aquaculture business.

Link to the thesis: http://hdl.handle.net/10037/6313

UiT The Arctic University of Norway
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

27 May 2014

Kari Skirbekk

A multi-proxy approach for reconstructing oceanographic dynamics during the Holocene. Development and application of benthic foraminifera as proxies in the polar North Atlantic

Microfossils from the seabed outside Svalbard and in the Barents Sea were examined to elucidate how these two sea areas have evolved over time. Present-day benthic foraminifers were analysed chemically in search of correlations between the amount of magnesium in their shells and the temperature of the water they live in. These correlations were then used to reconstruct temperatures back over time. The study revealed that different species were present at specific times of year and in specific water masses. This made it possible to reconstruct temperatures in different seasons, and also to trace inflow of warm salty Atlantic Water. One interesting finding is that inflow from the Atlantic after 1750 apparently led to increased melting along the coast of Spitsbergen. The results also confirm rapid warming of the water masses in the past half-century to century.

Link to the thesis: http://hdl.handle.net/10037/6996

UiT The Arctic University of Norway
Faculty of Science and Technology
Department of Geology

23 October 2014

Alexander Tøsdal Tveit

Microbial communities and metabolic networks in Arctic peatlands

Arctic peatlands store more than one sixth of all the organic carbon in soil on Earth. When microorganisms decompose this organic matter, the greenhouse gases methane (CH_4) and carbon dioxide (CO_2) are released. Temperatures are expected to increase in the Arctic, but it is not clear whether microorganisms will respond with increased activity, thus increasing the release of stored carbon. This thesis characterised microbial communities in peatlands in Svalbard. The peat was warmed and the responses of the microbial communities were studied, along with their release of CH_4 and CO_2. The studies revealed a complex community of microorganisms, dominated by bacteria but also including other prokaryotes and eukaryotes. A single bacterium species (*Methylobacter tundripaludum*) oxidised CH_4 to CO_2. When exposed to high temperatures, the microbiota adapted quickly, increasing their CH_4 production. New groups of microorganisms replaced those that preferred low temperature. Predatory eukaryotes became more active, keeping total biomass essentially unchanged. The net effect on CH_4 emissions will depend on the oxidation rate of *M. tundrapaludum.*

Link to the thesis: http://hdl.handle.net/10037/6162

UiT The Arctic University of Norway
Faculty of Biosciences, Fisheries and Economics
Department of Arctic and Marine Biology

2 May 2014

Sunil Vadakkepuliyambatta

Sub-seabed fluid-flow systems and gas hydrates of the SW Barents Sea and North Sea margins

This thesis work employed seismic data, information from sediment cores, and numeric modelling of gas hydrate stability to determine the extent and evolution of fluid migration systems and gas hydrates in the margins of the southwestern Barents Sea and the North Sea. Substantial fluid leakage was observed in the southwest Barents Sea, and this was linked to the major tectonic fault systems. It is likely that processes related to past ice ages (post-glacial rebound and erosion) have allowed fluid to leak from deep reservoirs. In several locations, gas and gas hydrates have accumulated near the seabed surface. Some of these pockets contain a relatively stable gas mix, which includes thermogenic hydrocarbons. However, the gas hydrate stability varies considerably across the southwest Barents Sea. These accumulations may be sensitive to changes in sea temperature. Global warming could potentially cause huge amounts of gas hydrates in the top 100 metres under the sea floor to melt within just a century or two.

Link to the thesis: http://hdl.handle.net/10037/6198

UiT The Arctic University of Norway
Faculty of Science and Technology
Department of Geology

25 April 2014

Carmen Vega

Nitrate stable isotopes and major ions in snow and ice from Svalbard

Increasing atmospheric content of reactive nitrogen, as consequence of human activities, has doubled the deposition of nitrate (NO^{3-}) in Greenland and Svalbard in the 20th century. The Arctic has fragile, nitrogen-limited ecosystems that can be altered by increased deposition of nitrogen. Stable isotopes of nitrogen and oxygen in nitrate can provide information on the sources of nitrogen oxides (NOx). However, nitrate in ice is difficult to interpret since it can come from several sources and is also subject to post-depositional processes. This thesis analysed stable isotopes in ice cores, snow and precipitation from Svalbard, to obtain records of natural and anthropogenic sources of nitrate. Comparison of ice core data and NOx and SOx emission profiles showed that the major source regions affecting Svalbard are Western Europe and North America, followed by Central Europe and former USSR. Since the 1950s most nitrate deposited at Lomonosovfonna comes from fossil fuel combustion, soil emissions, and forest fires. Studies of post-depositional change and percolation length revealed that although 45% of the annual snowpack melts, the atmospheric ionic signal from the past 60 years is preserved at annual or bi-annual resolution at Lomonosovfonna. The results suggest that stable isotopes

in nitrate from Svalbard ice cores are useful to describe different sources of NOx.

Link to the thesis: www.diva-portal.org/smash/get/diva2:709995/FULLTEXT01.pdf

Uppsala University
Faculty of Science and Technology
Department of Earth Sciences

Joint supervision with the Norwegian Polar Institute

27 May 2014

Daniel Ludwig Vogedes

Calanus spp. in the Arctic ecosystem – a story on predation, distribution and methodology

This thesis examines three closely related species of copepods that are central players in Arctic marine ecosystems. *Calanus finmarchicus*, *C. glacialis*, and *C. hyperboreus* link primary production to higher trophic levels through their ability to convert low-energy compounds to high-energy wax esters, which they store in their bodies in a lipid sac. This makes *Calanus* spp. attractive as food for fish and seabirds in the Arctic. Albeit similar, the three species also have important differences in terms of size, life history, and preferred marine habitat, making them useful, e.g., as indicators of climate. The thesis work provided improved methods to identify species, assessed the copepods' importance as food for little auks, and studied their behavioural characteristics. Copepod clustering behaviour could have impact both on the feeding success of little auks and the representativeness of sampling results. One of the studies revealed the first known evidence for diel vertical migration in the water column – even in the middle of the winter.

Link to the thesis: http://munin.uit.no/handle/10037/6807

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Joint supervision with the Norwegian Polar Institute and the Institute of Marine Research

19 November 2014

Andrey Voronkov

Hard-bottom benthic ecosystem in Kongsfjorden, a glacial fjord in the Arctic

Underwater rocky habitats constitute substantial parts of Arctic fjord ecosystems. There is a deficiency in complex surveys of hard-bottom fauna in the Arctic. The aim of this study was to increase the understanding of how animals are distributed on hard-bottom and their role in the marine ecosystem in the Arctic. A baseline study of biodiversity of hard-bottom animals in relation to environmental gradients in Kongsfjorden, a glacial fjord in Svalbard, is presented based on scuba diving collections. The inventory resulted in a total of 403 species, of which 47 species were recorded in Svalbard waters for the first time. Changes in diversity along the fjord axis and with depth as well as composition of the communities were determined. The studied habitats and transects should be counted as useful for climate change-related monitoring of diversity on hard-bottom and research on ecosystem functioning. Future studies could reveal new species at these sites related to altered distribution ranges and invasions of species.

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4 June 2014

Isabel Wendl

High resolution records of black carbon and other aerosol constituents from the Lomonosovfonna 2009 ice core

Black carbon (BC) is a short-lived atmospheric constituent that comes from incomplete combustion of biomass and fossil fuels. When deposited on snow and ice, BC reduces surface albedo, increasing absorption of incoming solar radiation and thus accelerating melting. BC data from the Arctic are sparse and existing climate models often underestimate the effects in the Arctic. Understand the current role of BC in the Arctic requires information on past BC concentrations. Instrumental observations cover only the most recent years and studies on arctic snow extend back only

several decades. Thus, natural archives, such as ice cores, can provide invaluable information on temperature, moisture, and atmospheric composition. Ice core research in the Arctic has mainly focused on the Greenland ice sheet. For a more complete picture, it is important to gather palaeo-climate information from sites outside Greenland. This work employed an ice core from the glacier Lomonosovfonna, Svalbard. Since Lomonosovfonna is relatively little affected by melt, the atmospheric signal is better preserved than at other arctic sites. The core was sampled at high resolution and dated using several methods, including detection of reference horizons, layer counting, nuclear dating, and a glacier flow model. This gave a robust chronology and assigned the ice at 149.5 m depth to the year 1222. The study allowed us to reconstruct the climate and environmental history of a low-altitude arctic site.

Link to the thesis:
www.psi.ch/lch/AlumniEN/Wendl_Thesis_PSIuUniBern_2014.pdf

University of Bern
Paul Scherrer Institut

Joint supervision with the Norwegian Polar Institute

17 October 2014

Magnus Aune Wiedmann

A trait-based assessment of the Barents Sea fish community: implications for vulnerability under environmental change

This study examined the fish community of the Barents Sea and assessed its vulnerability to disturbances such as fishing and climate change. Vulnerability depends on how sensitive the community is to stress, and on how readily it can adapt to stress. Adaptability was estimated from functional diversity in the population – how species differ from each other. Sensitivity was estimated both on community level (by calculating functional redundancy between species) and population level (by examining the sensitivity of individual species to fishing). Spatial variation in these traits was mapped throughout the Barents Sea for the years 2004–2009, characterised by warming water and shrinking ice cover in these waters. Vulnerability was relatively low in the central and southwestern Barents Sea, but increased farther north and east, mainly owing to less functional diversity and redundancy. Fish populations (including commercially attractive species) also appeared to be moving northwards, probably because of warming water masses. Given the vulnerability of the ecosystem in these northern regions, cautious management is warranted.

Link to the thesis: http://hdl.handle.net/10037/6384

UiT The Arctic University of Norway
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6 June 2014

Kristin Windsland

The invasive red king crab (*Paralithodes camtschaticus*): mortality, individual growth and dispersal

The red king crab was introduced to the Barents Sea in the 1960 by Soviet scientists; the aim was to improve local economy. The crab adapted well to its new environment and has gradually spread westward along the coast of northern Norway. As intended, it has become a valuable resource – but being a non-native species, it is also a potential threat to the ecosystem. This thesis work collected new knowledge about the crab's growth, mortality and dispersal. Individual crabs were tagged and recaptured to assess growth. The results provided more realistic estimates of growth parameters. Mortality during three time periods with different exploitation levels was estimated. Results showed increased mortality of both males and females since 1994. The crabs reach maturity just 19 months before attaining legal capture size, which suggests that recruitment to commercial fisheries may be weak. Studies of distribution revealed that the species extends its range both through rapid long-distance dispersal and through slow migration over time. Crabs are also moving out of the quota-regulated areas, which necessitates continued efforts to keep the population under control.

Link to the thesis: http://hdl.handle.net/10037/6735

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1 October 2014

Qin Zhou

Circulation and exchanges at high-latitude ocean margins: dynamical models and observations from instrumented seals

This thesis investigates circulation and exchange processes at high-latitude ocean margins by using analytical models, numerical simulations and hydrographic data. One question was how Atlantic Water transport is established as a topographically steered slope current. Comparison of results from a simplified analytical model and transport changes observed in the field indicate that geostrophy can be used to diagnose topographically steered barotropic flow, which makes it especially useful for high latitudes where topographic steering of ocean circulation is strong. Processes controlling water mass exchange in the eastern Weddell Sea were studied by examining over 11 000 hydrographic profiles collected by instrumented seals in 2008. Detailed analysis of these data, combined with an analytical model and numerical simulations show that Antarctic Surface Water is driven shoreward through Ekman transport, and spreads below the ice base through coastal downwelling. The same data, used in a coupled ocean–ice model including wave-induced mixing parameters, revealed that wave-induced mixing is important in modifying upper ocean properties.

Link to the thesis: http://munin.uit.no/handle/10037/5926

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Joint supervision with the Norwegian Polar Institute

24 January 2014

Ida Beathe Øverjordet

Element accumulation and oxidative stress variables in Arctic pelagic food chains: *Calanus*, little auks (*Alle alle*) and black-legged kittiwakes (*Rissa tridactyla*)

The main objective of this thesis was to examine how climate change might affect accumulation of elements such as cadmium and mercury in pelagic food chains in the High Arctic. Field studies were done in two fjords in Svalbard – one dominated by Atlantic water masses, the other by water from the Arctic Ocean. Heavy metal accumulation in black-legged kittiwakes and little auks varied significantly depending on season, year and site of sampling. These variations were most closely related to the birds' feeding ecology and diet. Oxidative stress in kittiwakes also varied from year to year, but there was no clear association between antioxidant levels and heavy metal accumulation. In laboratory studies, the sensitivity of two copepod species to mercury was also examined. *Calanus glacialis*, an Arctic copepod species, appeared to take up more mercury and be more sensitive to this metal than *C. finmarchicus*, a closely related copepod that prefers boreal and temperate water.

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Joint supervision with the Norwegian Polar Institute and SINTEF

17 October 2014

Ivar Stokkeland // Chief Librarian, Norwegian Polar Institute

New books published in 2014

Some samples from the library

The Dream of the North: A Cultural History to 1920 / by Peter Fjågesund
Amsterdam: Rodopi. 573 pp. (Studia imagologica; 23). ISBN 978-90-420-3837-0
While the focus here at the Fram Centre is very much on the natural sciences, we'd nevertheless like to begin with some cultural history.

Peter Fjågesund is Professor of British Literature and Civilisation at Telemark University College. He has spent eight years writing this in-depth review of the way in which we here in Europe have perceived the Arctic. (He also takes a quick detour into the Antarctic.) Chapter headings like "Music and art on ice", "Politicising the past" and "Arty Vikings" promise an exciting journey from the time of the Reformation and up to the start of the 20th century.

Tundra-Taiga Biology: Human, Plant and Animal Survival in the Arctic / by R.M.M. Crawford
Oxford University Press. 279 pp. ISBN 978-0-19-955941-1
Robert M.M. Crawford is Emeritus Professor of Biology at St. Andrews University in Scotland. He has previously described in detail how different plants survive under extreme conditions. Here, he ventures into the more general area of survival and includes both humans and other land-living animals. It is excellent to have a summary of what the researchers know about humankind's historic migrations to and within the Arctic. Crawford includes in his analysis modern developments in genetics and molecular biology. But the book also aims to appeal to the interested amateur. Crawford gives fine illustrations of the interaction between different groups of northern organisms. He is a good disseminator of the totality of existing knowledge of the terrestrial ecology of the Arctic.

Radioglaciology / ed. David Braaten. (Annals of Glaciology; Vol. 55, issue 67)
Cambridge: International Glaciological Society, 2014. 146 pp. (16 papers)
This anthology is based on an IGS symposium which summed up the extent of the ever-growing, exciting new areas of use for radar technology, drones and aircraft in the field of glaciology. "Radioglaciology" is about using radar to study glaciers and sea ice (instead of checking how fast you're driving your car).

Radar stands for "RAdio Detection And Ranging" and is a technology based on sending out radio waves and registering "echoes". Radar has been known for more than 80 years, but its area of application is being constantly expanded. The science of glaciology began using radar in the 1960s. As well as measuring the thickness of the ice, radar allows researchers to produce images of the structures within the ice, or to study the physical conditions beneath the ice. It was by using this method that, for example, the enormous Lake Vostok beneath the Antarctic ice was mapped.

The Politics of Arctic Sovereignty: Oil, Ice and Inuit Governance / by Jessica M. Shadian
London: Routledge. 270 pp. ISBN 978-0-415-64035-0

Jessica M. Shadian has a Ph.D. in Global Governance from the University of Delaware, where she studied indigenous peoples of the Arctic. As a researcher and something of an Arctic academic globetrotter, she has subsequently migrated to Quebec, Rovaniemi, Cambridge, Tromsø, Bodø and Stockholm. In this book, she analyses the way in which the history of the political organisation of the Inuits hangs

The Norwegian Polar Institute Library.
Photo: Ann Kristin Balto

together with the development of Arctic resources, and the consequences for western politics. Her analysis takes its point of departure in "the Westphalian system" – the idea that, following the Peace of Westphalia in Europe in 1648 (ending the Thirty Years' War), the principle of sovereign states was implemented internationally. That principle is being challenged by – not least – claims from indigenous people's organisations.

Ice Ship: The Epic Voyages of the Polar Adventurer Fram / by Charles W. Johnson
Lebanon (N.H.): ForeEdge. 330 pp. ISBN 978-1-61168-396-7
"Fram" is the name of the proud vessel that links much of Norwegian polar history together. I warmly recommend taking a trip to the Fram Museum in Oslo, where you can go on board the vessel herself! Regrettably, there is still a great deal of polar history that is not available in English. Here at last, though, is a thorough, detailed, but easy-to-read account of all the Fram voyages. Many people have helped the author in his work on the book, including staff at the Fram Centre.

Kald krig - varme mennesker: ny pomorhandel med Sovjet-Russland 1978-2003 / Kåre Karlstad
Sandnes: Commentum. 247 pp. ISBN 978-82-8233-259-0
Finally, we venture to include a book in Norwegian, which is the mother tongue of many of our readers. The author, Kåre Karlstad, is definitely a veteran (born in Finnmark in 1938). After many years as a ship's mate, Karlstad went ashore and retrained as a businessman. He was inspired by Jonas Lied, who opened up trade with Siberia a hundred years ago (with support from Fridtjof Nansen). While the Cold War was still very real, Karlstad worked to establish trust and trade across the Norwegian–Russian border. Here, the author gives us his own personal story about his life "against the current". Not all his projects were equally successful, but he accumulated unique expertise and a great store of experience along the way. Was it really easier to get a business project off the ground in the Soviet Union than in the era of "bandit capitalism" that came after it?

Ann Kristin Balto // Norwegian Polar Institute
Photo: Stig Hallgren // Norwegian Polar Institute photographic archive

St. Lucia celebrations in the Antarctic

See more photographs from the expedition in the Norwegian Polar Institute's photographic archive: http://fotoweb.npolar.no

It is Advent at the Maudheim research station in the Antarctic, where John Giæver and the team of scientists have long lived in isolation. More than a year has passed since they first set foot on the floating ice shelf where they will spend the next few years. Christmas is approaching, a Christmas they will have to celebrate far from home. To liven up the Advent season, they celebrate St. Lucia's Day on 13 December. A delightful St. Lucia serves freshly baked St. Lucia buns to expedition leader John Giæver.

The Norwegian-British-Swedish expedition to Antarctica in 1949-1952 was the first international research expedition to the continent. The expedition team returned in 1952 with unique data, including seismic measurements, which established that the ice in some areas was over 2 000 metres thick. The expedition was challenging, and John Giæver of the Norwegian Polar Institute had to deal with several critical situations. A geologist got a rock chip in his eye and, in order to save the sight in the other eye, the injured eye had to be removed. The eye amputation was carried out by the team's doctor, using home-made instruments and with members of the research team assisting the operation. But the most dramatic situation for the expedition must have been when a weasel tractor plunged into the sea in February 1951. Three people were killed. Our Swedish photographer, Stig Hallgren, survived the accident. He was rescued after a desperate struggle in the sea: soaking wet and ice-cold, he clung to an ice floe for hours, waiting for help.

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