FRAM CENTRE

FRAM FORUM

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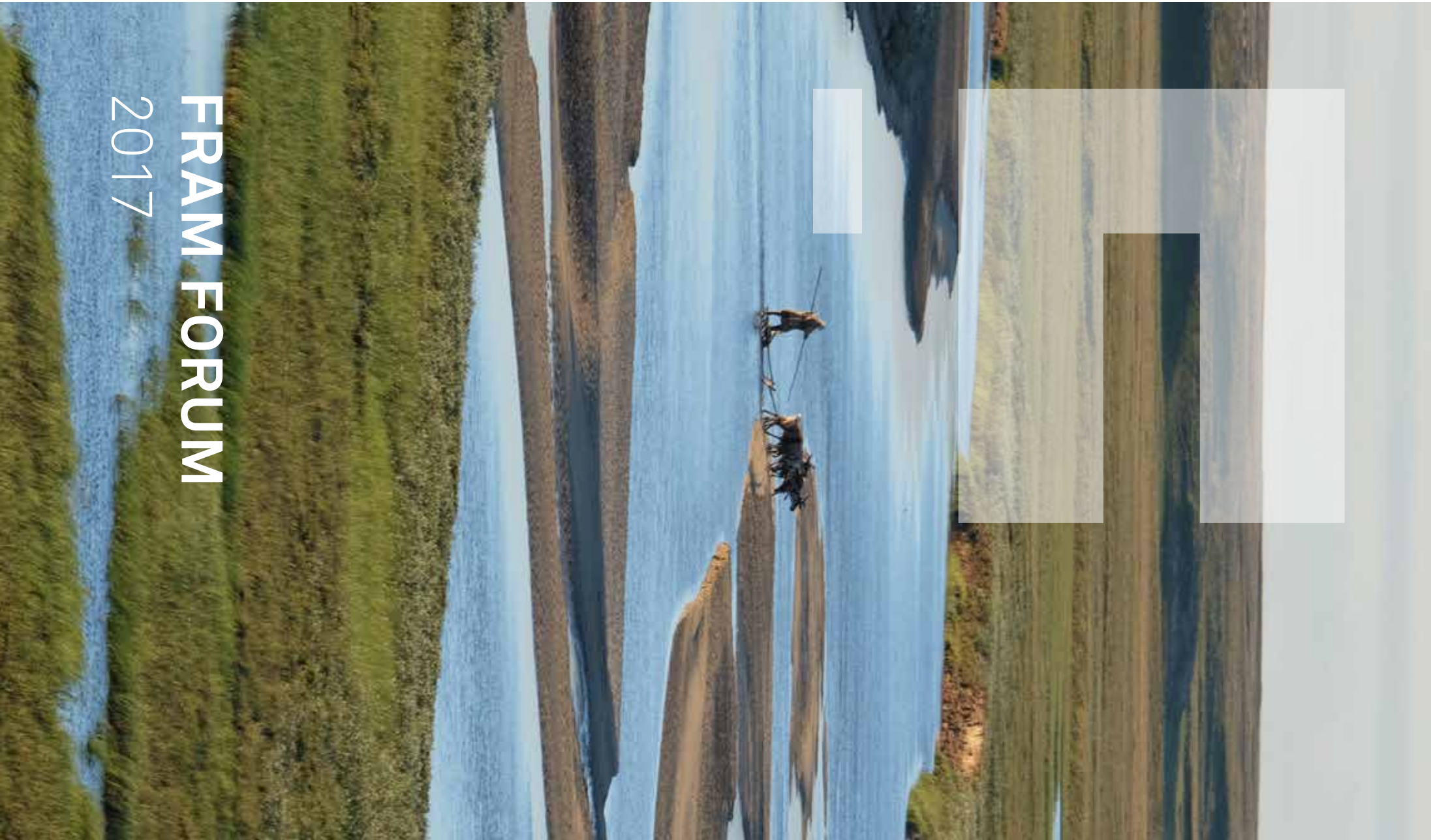

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TAKING THE LONG VIEW

This issue of Fram Forum has a recurring theme: long-term monitoring. Our Retrospective (p 38) sets the scene, describing measurements that have traced the health of the northeast arctic cod for 160 years. This data set, now called "Hjort's Hepatosomatic Index", is probably the longest biological time series in existence, but Fram Centre researchers work with shorter data series, too. The COAT project monitors a wide range of ecosystem components, and this issue reports from their work on vegetation and geese. KOAT, a sister project in Russia, monitors everything from tundra lakes to arctic foxes. MAREANO is helping keep an eye on organisms in the seabed. Other articles describe results from projects monitoring contaminants in the air we breathe and the food we eat.

Sadly, long-term programmes like these often come under fire when money is tight. Monitoring is an easy target when elected officials are beleaguered by irate taxpayers who complain about unnecessary spending. After all, scientists have been studying cod / vegetation / geese / lakes / foxes / the seabed / contaminants for years. Haven't they learned all there is to know by now?

Knowing a lot isn't always enough. Many of the threats we face come imperceptibly. The strength of time series is that they capture the slow evolution of trends over time. We can't sense changes in the carbon dioxide content of the air we breathe, but Keeling's iconic time series from Mauna Loa demonstrates that CO_2 levels have been rising for decades.

Long time series help us discover anomalies we might otherwise miss. "Instead of being caught off guard by unforeseen negative effects, we can take preventive measures", as Holte and Sætra write (p 60). The case of the ozone hole is an example.

In the mid-1900s, researchers measured ozone with the Dobson spectrophotometer; it is a precise instrument, but labour-intensive, requiring regular testing and calibration. When satellite-based ozone measurement became possible, most institutes gladly abandoned their old Dobsons. But the satellites would be measuring world-wide, generating unmanageable amounts of data. They were therefore programmed to discard "unrealistic" values before sending them to earth.

In the 1980s, scientists noticed an area over Antarctica with "missing data" on ozone, which expanded year by year. Fortunately, the British Antarctic Survey had continued its Dobson-based time series, and could confirm that ozone levels over Antarctica in spring had been dipping under "unrealistic" values since the 1970s. This discovery prompted research that ultimately led to the ban on ozone-depleting CFCs - and a Nobel prize.

The article on Hjort's index contains a word of warning. For over a century the northeast arctic cod's condition (measured as hepatosomatic index) correlated closely with temperature, rising and falling in parallel. Then a few years ago, *something changed* and the index fell despite rising temperatures. Sætra and colleagues write: "This shows how difficult it can be to predict the consequences of global warming and highlights how important it is, for research, that long time series are not broken."

But there is a problem: environmental protection agencies allocate resources for *monitoring*, while national research councils award funding for *research*. Projects that combine research and monitoring tend to fall through the cracks.

Even the longest, most extensive of time series realises its true value only when the data are put to use. Fram Centre partners are deeply involved in both maintaining and using several invaluable time series: data from the Tromsø Study help researchers understand human health and disease; atmospheric time series from Zeppelin Observatory in Ny-Ålesund inform research on climate; data from MOSJ (Environmental Monitoring of Svalbard and Jan Mayen) are crucial to research on our natural environment.

The value of a time series increases for every additional year of monitoring - even after the scientists "have learned all there is to know". If continuous environmental time series were to falter because of changed priorities or a funding hiatus, the negative ramifications would be profound.

Janet Holmén, Editor

Picture of the year

At the peak of the arctic summer, the Norwegian Polar Institute surveyed the pack ice north of Svalbard to estimate densities of polar bears, narwhals and bowhead whales. Taking good pictures of narwhals from the air is challenging because they tend to dive as soon as a helicopter approaches. We found that the best way was to ascend to above the 60-metre survey altitude as soon as we spotted the animals, then take pictures from high up and continue as we approached from above. The helicopter shakes quite a bit, so a fast lens is necessary to ensure sharp images. This picture was taken with a Canon fixed 200mm/2.0 lens. In our research, these images are used to identify and count animals. This picture shows three adult male narwhals (identified by their long tusks) in an open sea ice lead, their typical habitat.

Text and photo: Jon Aars / Norwegian Polar Institute

Ole Magnus Rapp

Research to the power of two

After dedicating ten years to meticulous study of the threats oil poses to polar cod, Jasmine Nahrgang shifted her attention to pursuits of a more personal nature. Thorough as always, she had twins.

Jasmine and Jørgen in their icy arctic element.
Photo: Ole Magnus Rapp

Jasmine, Jørgen, Sofie, and Alexander. *Photo: Ole Magnus Rapp*

ONCE THIS ARCTIC SCIENTIST starts something, she is captive to her own curiosity. One discovery leads to another, her interest grows, reactions to publications spur her on, and suddenly her curiousity has taken her research to completely uncharted waters.

But even though her head teems with thoughts of oil spills, students, and a species of susceptible little fish, her life currently revolves around her twins Sophie and Alexander, born five weeks early. They demanded and still demand mummy's undivided attention. So does husband Jørgen, burlier than the sweet little tots, and undisguisedly proud of his wife and everything she does.

MULTINATIONAL BEGINNINGS

That this German girl with French roots became a marine biologist was just a lucky accident, but after taking her Bachelor's degree in Canada and her Master's in Bordeaux, she simply had to go north. Once she arrived in Tromsø ten years ago, anything else was out of the question. From now on, the high north was the only place for her!

Assistant professor Jasmine Nahrgang has quickly become one of the most visible scientists at UiT The Arctic University of Norway. After some enjoyable years at Akvaplan-niva, where she earned her PhD, she moved to UiT's Department of Arctic and Marine Biology, bringing along two of her favourites: polar cod and oil spills. Or let's qualify that statement: the former is a favorite; the latter is a favourite *demon*.

She also brought with her a mixture of German thoroughness, French enthusiasm, Canadian Arctic experience, and a broad international education. On the job, she is organised and focussed; she pays attention to details and rarely lets anything pass without checking and double-checking.

A NATURAL INDICATOR

Her work on the polar cod as a marker of the changes in the Arctic has attracted attention from all over the world. This fish, which can grow to 30 centimetres in length, is a keystone species and an indicator of the condition of the ocean. Like a canary in a coal mine, it provides an early warning that all is not well.

Even though *Boreogadus saida* is a hardy little fish, it is affected by minute quantities of oil; its offspring have deformities and die. This means that one of the Arctic's most characteristic species may be in danger of disappearing, owing to a slightly warmer climate and increased human activity in its home range.

If the polar cod population were to decline or disappear, the repercussions would be far-reaching.

Two of Jasmine's babies: Sofie and a polar cod. *Photos: Ole Magnus Rapp (left) and Jørgen Berge (right)*

The main role of this little codfish is to be eaten. Adult polar cod are the preferred food of seals, whales, and seabirds, and its earlier life stages - eggs and larvae - are on the menu of other fish.

DEDICATED TO FISH AND FAMILY

Jasmine doesn't hide her strong commitment to the polar cod; her plea to the oil industry and shipping is equally strong: "Please be careful!" She has done long stints of intensive fieldwork in icy northern fjords, and has spent months hovering around the experimental tanks at the marine research station in Kårvika. She knows the polar cod's life cycle inside out, and has bred the fish in small tanks to tease out its most closely guarded secrets.

But now her life is all about maternity leave, the twins, and Jørgen. And about laying plans for more research when the time is ripe.

Let's start with Jørgen. Jasmine and her husband have more in common than most couples. The first time she noticed him was on a research cruise in the high north; she was a PhD student and he was a professor. In his research, Jørgen Berge is moving into uncharted territory. Along with his good friend and colleague Geir Johnsen, Jørgen has found an abundance of life in pitch-dark waters where most people assumed there was none. This is fascinating new knowledge.

Jasmine gradually discovered that it wasn't just the burly scientist's knowledge that was fascinating.

"But it wasn't a case of the professor flirting with his student. Not at all. I had to work hard before Jørgen had any inkling of my intentions", she reveals and he chuckles in the background.

Alexander has fallen asleep in daddy's arms, while Sophie does her best to charm mummy into nursing her yet again.

Jasmine gives a sly smile and reminisces about the last night of a long stay in Longyearbyen. She got Jørgen to invite her to dinner. He offered her warmed-up tinned stew, but it was a romantic evening nonetheless.

Now he's beginning to realise that she may be a research competitor, but he thinks he can handle it.

CHOICES AND DETERMINATION

"Jørgen's research fascinates me more and more", says Jasmine. "Perhaps I will eventually turn towards ecology, too. It's exciting to study the life histories of arctic animals. Environmental managers and others can't say much about effects without understanding the biology."

"I would actually like to work more with climate issues, preferably with a circumpolar perspective. And ocean acidification. But there's still a lot to be done regarding my friend the polar cod. There are a number of stress factors that the highly specialised arctic organisms must now deal with, factors that we scientists need to define."

Jørgen knows that when Jasmine has made up her mind, she gets things her way.

"She is dedicated and an extremely proficient scientist. Better than I am. If she starts something, it will be good", says Jasmine's husband and runs his huge paw gently down her back.

LIVING IN THE PRESENT

Sophie drops an energetic hint about more nursing, while Alexander sleeps on contentedly in daddy's arms. Their French grandmother, Jørgen's mother-in-law, declared long ago that one of the twins looks like mummy, the other like daddy. She has come north to help out; the two little ones happily take up a lot of space.

"Perhaps I shouldn't say this, but I'm looking forward to getting back to work", says Jasmine Nahrgang. "I miss the old days, when Jørgen and I spent half an hour in the car driving from Håkøya to the University and we could talk about work and anything else that cropped up."

PLANNING FOR THE FUTURE

At the Department of Arctic and Marine Biology, she has put together new courses and channelled students into disciplines needed for future research. She is currently supervising several PhD students online and is itching to be physically present in the academic community. The fact that the University is gradually doing away with her academic "babies" doesn't bother her, as long as the research continues to flourish.

Whatever happens, Jasmine intends to work up north and persevere with her research. She is currently preparing new courses for students and assembling knowledge she believes is necessary for tomorrow's research. She has simulated oil spills in icy waters. She has tormented her darling polar cod and measured what it and its offspring can tolerate.

"I'm the kind of scientist who goes in for it whole-heartedly. I'm inquisitive and discover stuff right and left and far ahead. My curiosity drives me on and I get my colleagues involved", says Nahrgang.

In January, Jørgen was out on another research cruise. Naturally, he was where the ocean is coldest and daylight is completely absent. He was surrounded by new technology, proficient engineers, clever students; there were unexpected snags and the team came up with creative solutions.

Jasmine is envious, but she's charging her batteries for her own next research efforts.

"Jørgen better watch out, because here I come! He will soon be taking paternity leave, and then...!"

Helge M. Markusson // Fram Centre

Looking for answers from indigenous peoples on the tundra

What happens when indigenous peoples are exposed to globalisation and assimilation? Is it possible for them to maintain their cultural heritage and continue with their traditional way of life? Zoia Vylka Ravna went to the Nenets on the Russian tundra in search of answers.

Gennadij knows all there is to know about reindeer, but is more interested in civil rights, history and Nenets happiness.
Photo: Zoia Vylka Ravna

Svetlana is one of the few who have returned to the tundra. She has not completed lower secondary school, and is now the mother of two small children.
Photo: Zoia Vylka Ravna

Two young tundra-dwellers.
Photo: Zoia Vylka Ravna

"THE CHOICES YOU MAKE have enormous impact on your way of life. Will you live in a traditional "chum" or a house? Will you get around by car or by reindeer and sledge?"

These questions come from Zoia Vylka Ravna. She is a PhD student at NIKU - the Norwegian Institute for Cultural Heritage Research at the Fram Centre in Tromsø. For her doctoral project at UiT The Arctic University of Norway, she is looking into how globalisation affects indigenous people. Her fieldwork has been done among the Nenets.

There are almost 45 000 people who can call themselves Nenets. Like the other 45 or so indigenous peoples in Russia, the Nenets still live off what nature provides, reindeer husbandry, and fishing. They live in eastern Russia, Siberia, and northwestern Russia. For her studies, Ravna went to the northwestern area, to the Yamal Peninsula, which extends 700 km into the Barents Sea.

UNIQUE CULTURE

"The Nenets are nomads who have had a unique way of life. The reindeer is central to the Nenets' culture. Without it, they would disappear as an indigenous people. They are born into a culture where traditional knowledge must be passed down from person to person if the community is to survive", says Ravna.

But the Russian education system requires the children of nomads to leave their camps and live at boarding schools for nine months a year. This means that young people have little time to acquire traditional knowledge, language, and spiritual values.

Among the Nenets, women are the custodians of traditional knowledge, and it is women who pass it on to small children. When the women leave the camps and move to villages and towns - voluntarily or because they have no other option - they set an example for young girls, who may also leave the traditional life on the tundra. The reindeer herder is left behind: a man who struggles to find a mate.

At the age of 53, Gennadij has been a reindeer herder under three different regimes: the Soviet, the "wild capitalist" and now the "Putinist".
Photo: Zoia Vylka Ravna

There is an increasing tendency that young women choose not to return to the nomadic life on the tundra after finishing their schooling. Conversely, young men more often return to the tundra and try to carry on with life as before without taking into consideration that there is a need to change their way of thinking. In addition we see that men's life expectancy is short, partly because of heavy alcohol consumption, which adds to the problem.

ON THE TUNDRA

Ravna has spent long periods on the tundra with the Nenets to understand their way of thinking. The objective of the research project is to develop a framework that allows the Russian education system and the Nenets' nomadic life adapt to each other.

"We have to go back to the formation of the Soviet Union to find the background for what is happening now. Before the Russian Revolution, the Nenets led a traditional nomadic life based on reindeer husbandry", says Ravna.

One of the aims of the Soviet state was to create an egalitarian society without gender restrictions, and this shook up the traditional gender roles of the nomads.

The other major change came with the Soviet system of agricultural collectives: reindeer were collectivised, though reindeer had never been collective property historically.

The period from 1920 to 1950 brought many changes that affected the transmission of traditional knowledge. One such change was forced relocation to larger villages because of the establishment of large collectives.

"It's still difficult for the Russian system to understand the perspective of indigenous people, which is often based on seemingly abstract ideas", says Ravna. "This is something we see in other parts of the world; the wider society has trouble understanding indigenous communities.

Zoia Vylka Ravna (in blue) has carried out her fieldwork with the Nenets on the Russian tundra. This photo was taken during the migration.
Photo: Stine Barlindhaug

"When they encounter something they don't understand they try to control it through rules and regulations. The Norwegianisation of the Sami people serves as a good example", says Ravna.

PERSONAL EXPERIENCE

In part, she uses her own cultural background to understand what is happening. Ravna is herself a Nenets and grew up in the Nenets autonomous region in the village of Krasnoje. In 1993, she moved to St. Petersburg to study history and culturology and shared student housing with many other students from various parts of northern Russia, Siberia, and the Far East.

"Yes, I suppose you could say I'm doing research into myself. But I think that's necessary to create a comprehensive picture of a long-term process such as the education of a nomad child - which should include the teaching of indigenous values and knowledge. That doesn't mean that researchers with a different background can't study the Nenets, but research should be done on a foundation of knowledge of their history. There's a need to change focus from regarding the traditional culture of nomads as difficult, outdated, and impractical, to looking at the advantages instead.

"The Nenets' way of life is complex but characterised by flexibility. They are able to adapt and are mobile. Their culture can provide people with new types of solutions, solutions modern-day research can't help us find", says Ravna.

NO RIGHT ANSWERS

There is no single "right" way to hand down traditional knowledge, but Ravna believes we need new methods of transmitting traditional culture from generation to generation.

"In a classroom, you're expected to acquire knowledge that makes you an efficient employee: a producer of material values. For the nomads, other values are important, such as living in harmony with nature and with other ethnic groups.

"Increased globalisation can have irreversible consequences for Nenets culture. The Nenets realise this, and at the same time they realise that they need outside help to adapt to this development. Still, the Nenets' knowledge is unique and must be their most important tool when adapting to a rapidly changing world", says Ravna.

These boys help their parents fetch water and firewood, and build the "mya". Then they play football and throw lassoes. In a few years they must choose whether to stay on the tundra or find another way of life.
Photo: Zoia Vylka Ravna

Researcher Zoia Vylka Ravna with veterinarian Denis Khudi.
Photo: Stine Barlindhaug

The Nenets' traditional dwelling tent is called "chum" in Russian, a word derived from the Udmurt language. The Nenets word for the structure is "mya". Today the whole family builds the mya, but previously only women and children built it.
Photo: Zoia Vylka Ravna

Åshild Ønvik Pedersen, Eva Fuglei and Øystein Overrein // Norwegian Polar Institute
John-André Henden, Rolf A. Ims, Edwige Bellier, Sandra Hamel, Filippo Marolla, Jarad Pope Mellard and Nigel G. Yoccoz // UiT The Arctic University of Norway
Audun Stien and Torkild Tveraa // Norwegian Institute for Nature Research

What is sustainable harvest when the climate is changing?

Major anthropogenic stressors, like climate change and harvesting, are affecting most ecosystems on Earth. In the SUSTAIN project, three of the strongest ecological research communities in Norway ask: How will ecosystems respond to the interacting effects of climate change and harvest?

MAJOR HUMAN STRESSORS, such as climate change and harvest, are currently affecting terrestrial, freshwater, and marine ecosystems. Although each individual stress factor can have far-reaching implications, the combined effects of harvest and climate change may be greater than the sum of the two. Such interactive effects are poorly studied. This is problematic because interactions may alter ecosystems in unexpected ways, potentially affecting ecosystem services, that is, the direct and indirect benefits ecosystems provide to humankind. When ecosystems fundamentally change, current harvest levels may not be sustainable and knowledge-based management may no longer be valid. How can researchers, managers, fishermen, herders, and hunters prepare for this new and challenging reality?

SUSTAIN

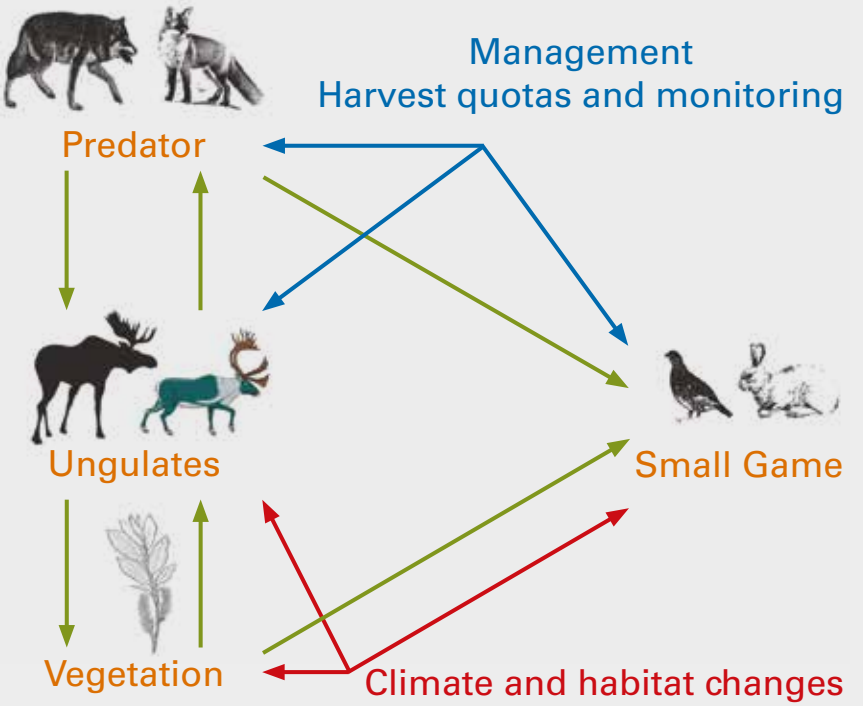
The project *Sustainable management of renewable resources in a changing environment: an integrated approach across ecosystems* (http://www.sustain.uio.no/) has the ambition to use an ensemble of high-quality ecological models to answer these challenging questions. The emergent and accelerating environmental changes have fostered a unique partnership between internationally-leading ecologists at three universities in Norway (UiT, UiO and NTNU), scientists from several research institutes, and stakeholders spanning from environmental policy and decision makers to Sami reindeer herders and the forestry industry. Together, they will develop frameworks for management strategies that contribute to resilience in a range of marine,

Photo: Ruben Eidesen

SUSTAIN is a nationally coordinated research project in the ECOSYSTEM programme of the Research Council of Norway (2016-2018) and received additional financial support from the Fram Centre's Terrestrial flagship programme.

A conceptual model outlining the relations that will be addressed in SUSTAIN's case studies on terrestrial low- and sub-Arctic ecosystems.

Graphics: Jan Roald / Norwegian Polar Institute



aquatic, and terrestrial ecosystems under changing climatic conditions. Several of SUSTAIN's "case study ecosystems" are within the geographic domain of the Fram Centre, such as the Barents Sea, the high arctic tundra in Svalbard, and both the low arctic tundra and the boreal forest in northern Norway.

STRATEGIC FORESIGHT

To ensure stakeholder involvement, SUSTAIN will use a *Strategic foresight protocol,* which provides a framework for structured contingency planning to deal with surprises that may threaten managed ecosystems. The project builds on and extends the concept of adaptive management with increased attention to foresight analyses. The structured process involves the stakeholders, making them active participants in the entire research process, from setting the goals to translating results into practical sustainable management strategies and actions. The *strategic foresight* protocol will help to: 1) Identify possible ecosystem surprises from interacting effects of climate change and harvest and early environmental signals of their emergence; 2) Provide guidelines on how research and monitoring systems can improve to anticipate and detect surprises; and 3) Determine how management can implement immediate actions and new strategies that counteract the negative impacts on both single species and entire ecosystems. The cross-ecosystem scope of SUSTAIN will transcend the conventional "box thinking" of freshwater, marine, and terrestrial ecological sub-disciplines, and the stakeholder involvement will break down the barriers between academics and stakeholders. Thus the SUSTAIN effort aims to counteract fragmentation within Norwegian environmental science and establish new long-lasting relationships.

CHALLENGES

Climate change and its interactions with other drivers are the largest challenge for future sustainable management of harvest - especially in the high north. SUSTAIN researchers have ideas for how to use data and ensemble models to predict responses of harvested species to possible future climate- and harvest scenarios. The fact that environmental stochasticity and systematic trends are influencing species abundances, and hence the harvest size, are fundamental premises. Thus, it is important to investigate whether harvest may act to increase or reduce the impact of climate change on the abundance and variability of

Photo: Nicolas Lecomte

species and ecosystems. Another important question is whether existing data and models are sufficient to predict such responses, and particularly whether certain aspects of current ecosystem monitoring and modelling need further improvements to allow robust research-based management strategies to be developed. Such perspectives and questions are likely just as important to the stakeholders as to the researchers. In SUSTAIN the joint research efforts and the stakeholders' practical approach to harvest management are combined to explore alternatives and new strategies. SUSTAIN will likely not provide any "final solution" to management of harvested species in a rapidly changing environment, but will cover new ground and provide fruitful partnership and intersections between research, management, and resource-users working to counteract the climate change effects on harvested species and ecosystems.

Photo: Elise Strømseng

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Eeva Soininen // UiT The Arctic University of Norway
René van der Wal // University of Aberdeen

The Green Arctic – Plants as cornerstones in terrestrial ecosystems

Svalbard's arctic landscape is characterised by glaciers, snow, barren mountains, and rocky soil. It's a tough place for all living things, yet many creatures thrive here. They owe their survival to hardy plants: mosses, grasses, and herbs are the cornerstone of Svalbard's terrestrial ecosystem.

Much of Svalbard is an arctic desert. Satellite photos show very little vegetation, and visitors must look close to admire the small, scattered flowers that hunker down among stones and gravel. But this land in the far north has green spots. We find small patches of productive vegetation, with a diverse flora of grasses, herbs, and mosses. These plants are crucially important for the successful functioning of the entire land-based system. Without them, there would be no reindeer, no ptarmigan, no geese. The permafrost would thaw more easily and erosion would increase. Plants are the foundation on which the terrestrial food web rests. In our research, we focus on these green "cornerstones" and factors that could alter their resilience and function, with the aim of making plant monitoring both efficient and relevant for management of the ecosystem as a whole.

WHY MONITOR THE GREEN STUFF?

At present, the life of a plant in Svalbard is not rosy. Weather conditions in both summer and winter vary more than they used to. The summers are warmer but also either wetter or drier than they were a few decades ago. The winters are not as cold as before, and it rains more. People come in large and small hordes and their boots leave marks on the vegetation. Thousands of year-round residents (reindeer and ptarmigan) need to eat, and the same goes for a rapidly growing number of summer visitors (geese). In 1965, about 15 000 pink-footed geese came to Svalbard every year to breed; by 2016 their numbers had increased almost fivefold. Yet, cliff-breeding seabirds are declining, and thereby the amounts of natural fertiliser raining down from numerous cliffs.

According to the Svalbard Environmental Protection Act, Svalbard's natural environment is to be preserved as untouched by humans as possible. The knowledge obtained through monitoring is expected to inform this management objective. By monitoring Svalbard's "green stuff" we will obtain insight into the most important ongoing changes affecting the high-arctic vegetation, and - where possible - distinguish between human impact and natural variation. The monitoring will inform us about the consequences of climate change. We need to pay particularly close attention to those components of the vegetation that have important roles in the wider ecosystem.

WHAT ARE WE ON THE LOOKOUT FOR?

Svalbard's flora includes 180 vascular plant species and several hundred species of mosses, lichens, and liverworts. Combined in diverse assemblages, they form many different types of vegetation that vary greatly in their potential for change and their ability to tolerate disturbance by both humans and animals. Svalbard is vast, and it is impossible to monitor all the plant species or vegetation types across the whole of the archipelago. In deciding what to monitor, we use the principles described in COAT - Climate-ecological Observatory for Arctic Tundra (see Ims et al. 2013). A selection based on key concepts (e.g. *sensitivity to climate change / key function in the food web / maintaining arctic biodiversity and ecosystem services / management relevance*) ensures efficient monitoring.

MOSSES AND FRIENDS: FOOD WEB CORNERSTONES

How rapidly plants are able to increase their biomass when affected by changes in climate or other environmental factors, such as grazing animals, is often linked to a plants' inherent growth rate. Given good growing conditions, vegetation characterised by herbs

Grasses, herbs and mosses form productive vegetation with high biodiversity.
Photos: Lawrence Hislop and Leif Einar Støvern / Norwegian Polar Institute

Without nutrient-rich plants, reindeer, geese, and ptarmigan would not be able to inhabit Svalbard. The future of the vegetation in Svalbard depends on both climate and the grazing animals.
Photos: Lawrence Hislop (left) and Isabell Eischeid (right) / Norwegian Polar Institute

and grass can burgeon rapidly. On the other hand, slow-growing, woody plants such as polar willow and arctic bell heather will be unable to increase their biomass as quickly. If we imagine a world where the summers become warmer and longer, and there is enough moisture for mosses to remain in place and form an intact layer, then the productive grass and herb species will have a protective blanket of moss in which to thrive. Even today, under the harshest climate conditions in the north of Svalbard, the mountain slopes are green with moss, herbs and grass - vegetation that stands out in an otherwise barren landscape. This indicates the potential of even the far north in terms of plant productivity.

Mosses and their friends - grasses and herbs - do more than just ensure a rich diversity of common plant species: they also provide a home for species that are rare in Svalbard. Insect and microorganism diversity is high in productive vegetation, and moss tundra provides vital food for Svalbard's endemic grazers, the Svalbard reindeer and the Svalbard rock ptarmigan. Herbs and grasses decompose quickly, keeping nutrients in circulation. Grass roots can stabilise the soil, and a thick carpet of moss keeps the ground cold, so that the permafrost thaws more slowly and little of the "old" carbon that is locked below the surface is released to the atmosphere. Moss tundra is an important part of the landscape and a distinctive arctic ecosystem - and it has the potential to change rapidly. The tiny herbs, the somewhat anonymous grasses and the ubiquitous mosses that together make up the moss tundra vegetation serve as "cornerstones", forming the foundation on which much of the terrestrial arctic ecosystem rests.

THE WILD CARDS

Climate does not change in isolation, and warming is not the only environmental challenge facing the plants. When we put our imaginary world to one side and include factors from real life, it immediately becomes more difficult to predict which plant species will thrive under future environmental conditions. The grazing by Svalbard reindeer and geese, the trampling feet of grazing animals and humans, the fertilising effect of seabirds and grazers, and the arrival of plant species from outside of Svalbard: all these are wild cards that could turn everything upside down. The seabirds nesting on cliffs deposit tonnes of guano, thus bringing fresh nutrients from sea to land. Many of the seabird populations are decreasing and we do not know how long it will take before the reduced influx of fertiliser will start to limit plant growth. The

grazing animal populations are affected by climate both in Svalbard (for instance the stationary Svalbard reindeer) and in the wintering areas further south (for instance the migratory pink-footed goose).

The pristine Arctic attracts tourists, who often visit seabird cliffs or moss tundra where the vegetation is susceptible to trampling. In places where the moss cover has been trampled and lost, the risk of soil warming will increase, leading to less permafrost and greater danger of landslides and ground collapse. People and animals from afar can also bring in plants that are alien to Svalbard's flora. The moss tundra and the seabird cliffs are in particular danger as potential sites for the spread of species such as the "black-listed" cow parsley. If we are to be able to understand future changes in Svalbard's plant life, we must keep a sharp eye on both the climate changes and the "wild cards".

WHAT'S THE BEST WAY MONITOR VEGETATION?

We want our vegetation monitoring to be comprehensive, yet efficient. In COAT (Climate-ecological Observatory of Arctic Tundra), we are constructing a vegetation monitoring strategy that focusses on the green cornerstones of the terrestrial ecosystem: the plants in moss tundra. We combine the data we gather about plants with measurements of factors that can alter the strength and function of the cornerstone species. To do this, we link climate-related data (snow, ice, temperature, etc.) and time series of grazing animals to our data on plants, simultaneously keeping an eye on trampling, and incoming non-native plant species. In this manner, we will make the vegetation monitoring relevant for the management of Svalbard's terrestrial ecosystem.

Efficient monitoring of vegetation requires a combination of new technology and good old-fashioned field biology. The quality of satellite images is constantly improving, and we can use them to monitor some aspects of changes in the vegetation. However, this kind of remote sensing leaves a lot of uncertainty as to which plants are actually changing. In addition, as we have seen above, the various plants and types of vegetation play widely different roles, and we need more knowledge about that as well. Therefore, we will combine remote sensing with field monitoring such that we can reveal how changes in climatic conditions, grazing animals, cliff-breeding seabirds, and a set of specific human activities influence moss tundra across large parts of Svalbard.

Combining site-specific fieldwork and large-scale remote sensing material also brings other obvious benefits. Climate models that provide maps predicting snow distribution, for example, or temperatures throughout the year's seasons are crucially dependent on correct input data from field measurements. There are currently not enough climate observations to give adequate spatial resolution. Our vegetation monitoring strategy therefore includes gathering field data for selected climate variables.

A lot of vegetation-based research has been done previously in various locations across Svalbard, and many of those sites have been selected for COAT long-term monitoring. That way, location-specific understanding can be built from, and supplemented with, data from other sites for which no such longer-term data exist. Findings from this network of monitoring sites - old and new - will be combined with monitoring of the grazing animals and climate, and scaled up through the use of remote sensing approaches. By keeping an eye on the plants that are cornerstones of Svalbard's tundra ecosystem, COAT vegetation monitoring will itself become a cornerstone in efforts to monitor wider terrestrial ecosystems.

FURTHER READING:

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The authors of this article are collaborating on establishing plant monitoring within COAT – Climate-Ecological Observatory for Arctic Tundra.

Åshild Ø. Pedersen and Eva Fuglei // Norwegian Polar Institute

Goose density influences predation on ground-nesting birds in Svalbard

The number of geese that spend the summer in Svalbard has increased dramatically in recent decades. Geese nest on the ground, where their eggs and chicks are easy prey for the arctic fox. If goose nests or colonies attract foxes, how might that affect the survival of other birds that nest on the tundra?

SVALBARD HOUSES a simple vertebrate community where the arctic fox is the main predator. The ecosystem lacks both small rodents and specialist predators. Therefore the size of the arctic fox population, and the number of prey the foxes eat, will change depending on what prey is available from terrestrial (birds and reindeer) and marine (seabirds and seals) ecosystems. Arctic-breeding geese, which migrate from temperate ecosystems, are the preferred prey of the arctic fox in summer.

During the last decades, the number of geese in Svalbard has increased rapidly due to climate change in the overwintering areas and on the breeding grounds (see goosemap.nina.no; coat.no). This may lead to changes in predation pressure – and not just on the geese. Being a non-specialist predator, the fox might equally well raid the nests of less abundant ground-nesting tundra birds.

A new pilot study by Fram Centre researchers used two valleys contrasted by goose density to explore whether ground-nesting birds of conservation concern (e.g. the endemic Svalbard rock ptarmigan, locally red-listed waders and the archipelago's only passerine species, the snow bunting) experienced elevated nest predation in areas where geese were abundant. The study, involving artificial nests, actually demonstrated the opposite: the risk of nest predation for birds of conservation concern was reduced.

This result is compatible with at least two different hypotheses concerning predator–prey interactions: apparent mutualism (e.g. high availability of main prey reduces predation on alternative prey) or prey swamping (e.g. overabundant main prey buffers predation on alternative prey). It also contrasts with results obtained in more complex arctic ecosystems.

Goose is the preferred prey of the arctic fox in summer. Foxes feed on both pink-footed goose and barnacle goose, as shown in this photo taken on Brøggerhalvøya, Svalbard. There is a strong correlation between gosling survival and arctic fox numbers.
Photo: Finn Sletten / Norwegian Polar Institute

The study highlights the need for integrating studies with artificial nests as part of the long-term monitoring efforts within the Fram Centre project *Climate-ecological Observatory for Arctic Tundra* (COAT) to effectively monitor the interactive effects of predators and goose abundance on birds of conservation concern.

Fram Centre co-authors of the study currently under scientific review:

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Food and health security in the Norwegian–Finnish–Russian border region

In many regions in the Arctic, hazardous substances from local and far-away sources are found at levels that may threaten the health of both humans and the environment. We have studied the impact of local industry on food safety and human health at the northern end of the Scandinavian peninsula.

IN THE REGION AROUND the borders between Norway, Finland, and Russia, local industrial activities associated with natural resource extraction have been a substantial source of local pollution. Although there is concern about the long-term consequences of this pollution, the industrial activities also provide jobs and economic benefits to local communities. To date there has been a lack of cross-border data on contaminants in the local foods collected from nature and their impact on human health. Likewise, little has been known about what shapes the local populations' food security concerns and what impact those concerns have on behaviour and policies.

The main objective of our project was to assess the impact of industry on food safety and human health in this High North border area. To this end, we investigated concentrations of contaminants in local food and in pregnant women, and conducted questionnaire surveys to study how the region's inhabitants perceived potential risks.

CONTAMINANTS IN FOOD

More than 200 food samples were collected from Norway, Russia, and Finland. The local foods included various fish and bird species, reindeer, moose, mushrooms and berries. Analyses show that the Pechenga Nikel refinery is responsible for elevated concentrations of several metals in local foods. More specifically, fish, mushrooms, and berries on both the Norwegian and the Russian side of the border (sampled close to Nikel) show elevated concentrations of nickel, copper, and cobalt; some samples also had elevated levels of cadmium and lead. The mercury concentrations are also higher than normal in some fish species in the area, but the link to the Nikel refinery is not clear. Apart from dioxins in reindeer, and mercury in fish from certain lakes, none of the contaminants in local foods are present in concentrations that make the food unsafe for human consumption.

Surprisingly, reindeer meat collected in Norway

The reindeer that wander around the Norwegian–Finnish–Russian border provide meat that can be eaten locally or sold to bring cash into the border communities.

Photo: Geir Rudolfsen / Norwegian Radiation Protection Authority

contains more dioxins than was recently reported in reindeer meat from Finland. Dioxins and dioxin-like substances are classified as both toxic and carcinogenic, but there are unfortunately no international guidelines as to what levels of these compounds are tolerable in reindeer meat. The concentrations detected have therefore been compared to EU maximum limits set for meat and meat products from bovine animals and sheep.[1] The dioxin concentrations we uncovered give us reason to believe that families consuming large amounts of reindeer products, especially products rich in fat, risk exceeding tolerable amounts of dioxins. We have reported these findings to the appropriate Norwegian authorities and further investigations have been launched to clarify the extent of this problem. In addition, the exact sources of the dioxin must be identified.

1 http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32011R1259&from=EN

Monitoring of radioactivity in the same food products showed generally low levels of radioactive caesium, below the national activity limits for food set in all three countries. Thus, the caesium content in environmental samples collected in 2013-2014 does not indicate a risk of human health issues or environmental impact.

CONTAMINANT BURDEN IN PREGNANT WOMEN

Blood samples from expectant mothers in Russia, Finland and Norway contain toxic elements, but the concentration patterns differ slightly. Cadmium concentrations are higher in Russian women, and selenium concentrations are lower in samples from women living in northern Norway. The levels of persistent organic pollutants were low and of no concern in the Norwegian and Finnish cohorts, but there were some interesting differences compared with Russia. The levels of both dichlorodiphenyldichloroethylene/dichlorodiphenyltrichloroethane, better known as

Photo: Geir Rudolfsen / Norwegian Radiation Protection Authority

DDT, and another pesticide called hexachlorobenzene (HCB) were higher in the blood samples from Russian mothers. Use of DDT and HCB has long been banned through the Stockholm Convention (a global treaty), but the levels detected in these samples indicate recent, local use. The overall conclusion is that the average levels of toxic elements and organochlorines in pregnant women residing in the border area are not alarmingly high and not much higher than in women from this region that do not reside in the border area. On the other hand, some individual Russian samples contained levels that could imply heightened exposure of the unborn child.

DO PEOPLE DARE TO EAT LOCAL FOOD?

An important part of the project involves assessing how the region's inhabitants use local food, how they view the risks posed by food contamination, and what socioeconomic consequences it might have. For this part of the project we conducted a questionnaire survey investigating risk perception and knowledge about local pollution and food safety among the populations of Pechenga, Inari, and Sør-Varanger.

People in the Norwegian-Russian-Finnish border region generally appear to be concerned about pollution by hazardous substances. This is affecting the populations' consumption of local food and water, particularly in the Pechenga region. We found that risk perceptions vary in character between municipalities, most likely owing to differences in the pollution situation, in exposure to local contaminants through air and food, in cultural and political systems and values, and in how the risk is communicated.

The survey results also show that people's concerns about pollutants vary greatly between different groups. The largest differences were found between Pechenga and the two other regions surveyed, but there are also systematic differences of risk perception between genders, education levels, and age groups. When asked to score their worry about environmental pollution on a scale from 1 to 10, a majority - 52% - of the respondents from Pechenga chose the highest alternative. In Inari and Sør-Varanger, by contrast, far fewer gave the highest score: only 19% and 6%, respectively.

The countries differ in terms of what types of food items the inhabitants gather from the local landscape and eat. People in the Inari region appear more likely to fish, hunt, or gather local food than people in other regions. Inari residents generally eat local produce more often than people from Sør-Varanger, who in turn eat it more often than the people from Pechenga.

That said, the pattern for mushroom gathering differs from that of other food items.

Comparison of what the study participants considered a risk in the region with what environmental experts considered a threat, revealed that the average public opinion coincided well with that of the experts, with a few interesting exceptions. The findings from Sør-Varanger could suggest that the citizens have received relevant information (or sought it out on their own), and have understood the risks. Nonetheless, in both Sør-Varanger and the other municipalities surveyed, a majority of the people express a desire more information and state that greater attention should be focussed on local pollution issues.

RISK COMMUNICATION: IMPORTANT BUT TRICKY

Given some of the results about hazardous substances in animals and food, it seems likely that stricter pollution control is required, while the results of the surveys highlight a need for additional general information about the pollution situation and improvements in targeted risk communication. It also appears that risk is not communicated in a consistent way. The message can be shaped as much by political or cultural practices (trust or lack of trust in authorities: government, environmental groups, industry, research institutions) as by the data themselves. Some industry analysts claim to be at a disadvantage with regard to risk communication, as their statements are not considered as trustworthy as those coming from environmental organisations (for example). This demonstrates that risk communication practices are embedded within and influenced by different values articulated through political goals, as well as by the data. This in turn affects how community members perceive their own security.

GETTING THE MESSAGE OUT

Our results have been disseminated in various venues: several international and national conferences, two separate summer schools (the Barents Summer School and Collaborative Arctic Seminars in Epidemiology), a Barents health conference in Kirkenes, a public meeting in Svanvik, and meetings with the Norwegian food safety authorities. In addition, several papers are being prepared on this topic for publication in peer-reviewed journals.

PROJECT OUTCOME SO FAR

The project has contributed greatly towards strengthening cross-border cooperation between Norway, Finland and Russia, and has achieved several joint environmental assessments. In general, we have been able to enhance knowledge on contaminants in key species (food products) that are used for local consumption as well as being of commercial value, specifically reindeer, moose, fish, birds, mushrooms and berries. Local food - especially in the area northeast of the Nikel refinery - sometimes shows elevated levels of a number of toxic elements but the concentrations are not of major concern for human health. The project has revealed that populations living along the borders between Russia, Norway, and Finland differ in their diets, everyday activities, and trust in authorities. Many of these results are being analysed for publication in scientific journals. The work also made it clear that risks to human health are calculated according to different protocols in these three countries, and - especially - that the national follow-up strategies differ. This project represents an excellent starting point for further research, and cooperation between the food security agencies responsible for formulating food consumption guidelines in the three countries.

PARTNERS:

Fram Centre partners: NILU, Akvaplan-niva, NRPA, NORUT, UiT The Arctic University of Norway

External partners: Fylkesmannen i Finnmark, Vadsø, Norway; Northern and Environmental Issues; Thule Institute, University of Oulu, Oulu, Finland; Finnish Meteorological Institute, Helsinki, Finland; Murmansk Country Birth Registry, Murmansk, Russia; Institute for Ecological Problems, Kola Science Centre, Apatity, Russia; Northwest Public Health Research Center, St. Petersburg, Russia

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Randi Solhaug // UiT The Arctic University of Norway

Monitoring animal life on the Russian tundra

Welcome to Yamal, a peninsula in western Siberia that extends over 700 km from the forest tundra transition to the high Arctic. Most of the peninsula is permanently frozen sandy ground. Every summer for nine years, Dorothee Ehrich has visited Yamal to study its teeming fauna.

YEARS OF RESEARCH on the vast Russian tundra are showing changes in the ecosystem. Dorothee Ehrich, from the Department of Arctic and Marine Biology at UiT The Arctic University of Norway, and her Russian colleagues from the Arctic Research Station of the Insitute of Plant and Animal Ecology of the Ural Branch of the Russian Academy of Sciences, monitor the ecosystem to find out who eats whom among the peninsula's birds and mammals, and - not least - how this is affected by climate changes.

Their monitoring is part of the project called KOAT-Russia, "little sister" of the Fram Centre project Climate-ecological Observatory for Arctic Tundra (COAT).

DIVERSE FOOD SUPPLY

Yamal is a featureless plain, but fertile and full of life. There, predators find a diverse and plentiful supply of plant-eating prey, such as voles, hares, ptarmigan, and ducks. But the supply is not totally reliable. There are major population fluctuations among rodents: voles, and especially lemmings, exhibit multiannual cycles. During years with few herbivores, the predators also breed less.

To find out how many herbivores there are each year, and determine natural population fluctuations, the scientists catch small rodents and count hare and ptarmigan excrement.

"This also tells us a bit about the animals' activity and how they use the habitat", says Dorothee Ehrich.

When she and her colleagues are out on fieldwork by the Erkuta river on Yamal, they live in a semi-permanent camp consisting mainly of tents. The living standard is basic, but at least they have access to a motorboat when they head upriver to document the fauna. Among other things, they count and tag birds and check arctic fox dens. And they walk a lot.

"We often work for as long as eight hours before going back. Then we generally do a bit more work at 'the office' we've set up in the camp."

Dorothee Ehrich and a colleague trapped a long-tailed skua to band it and equip it with a geolocator, a small device that stores information about the bird's annual migration. *Photo: Evgenia Viguzova*

COMPARISON WITH VARANGER

If we compare Yamal with Varanger in Finnmark, which has tundra at higher altitudes inland and lacks permafrost, we find some similarities. For instance, many of the same species live in both places. However, there are also differences.

The arctic fox is common on Yamal, which - unlike Varanger - offers favourable conditions. Granted, Yamal's foxes had few pups last summer, but there was also a decline in the number of voles, a common prey for the arctic fox. Yamal essentially lacks the arctic fox's main rival: the red fox. The arctic fox is well adapted to the harsh Siberian winters and can live off its fat reserves for several weeks. The red fox needs more resources and therefore stays further south.

If temperatures should rise, and if the availability of food in the winter were to increase, the red fox population might expand northwards. This would oust the arctic fox, which avoids the red fox. And that is exactly what has happened in Varanger. Earlier research

Scientist Dorothee Ehrich on the tundra of Russia's Yamal Peninsula. She has come here for fieldwork nine summers in a row. *Photo: Aleksandr Sokolov*

An arctic fox pup in front of its den. On the Russian tundra, the arctic fox has so far had favourable conditions, but there are signs that this may change. This image was captured by an automatic camera.

carried out at the University of Tromsø has documented that reindeer carcasses in the inland helped the red fox survive the winter.

"So far it has not been a problem, but monitoring with automatic cameras shows that what happens in Varanger is also beginning to happen on Yamal as well", says Ehrich.

FERTILE, OVERGROWN LAKES

Another development, which has been registered in the area through satellite monitoring carried out in collaboration with Finnish colleagues, is that several lakes are drying up. The bed of a dried-up lake is full of nutrients and is therefore relatively fertile. On the ground, this is apparent from the presence of masses of flowers and waist-high grass - not exactly a common sight in the Arctic.

"These overgrown lakes look like small, green islands in the middle of the tundra. And we've observed that voles have moved in and gained a foothold. We don't know how long these 'hot spots' last, but things usually happen slowly on the tundra", says Dorothee Ehrich.

They have also observed that conditions for the rough-legged buzzard have deteriorated. The relative scarcity of voles has meant less food for the rough-legged buzzard, and there have been fewer buzzard nests than usual on Yamal.

ANTHRAX OUTBREAK

Over recent years, temperatures have been rising steadily on the Russian tundra.

"The summer of 2016 was extraordinarily hot", says Ehrich. "We had over 30 degrees for several weeks. The tundra dried out and there were several fires."

The unusually high temperature was probably also the cause of an anthrax outbreak in the area in July. As many as 90 people may have been infected, and several thousand reindeer died because of the outbreak. The heatwave led to thawing in the top layer of the permafrost, and Russian authorities presume that this released anthrax spores that had lain dormant in the ground since the last outbreak in 1941. The heat itself also played a role in weakening the animals. Moreover, compulsory vaccination of reindeer was

The field camp by the Erkuta river on the Yamal peninsula may be a bit primitive, but the surroundings are magnificent.
Photo: Dorothee Ehrich

Waist-high grass is not common on the tundra. This stand is growing on the bed of a dried-up lake – an unusually fertile place.
Photo: Dorothee Ehrich

abolished in 2007, and that obviously left the reindeer susceptible to the bacteria.

Ehrich and the research team were not near the affected area, but as they had limited contact with the outside world and little up-to-date information, the group decided to end their stay on the tundra earlier than originally planned.

"We lost some research time that way, but it was our own decision. When we're on the tundra, people can only reach us by satellite telephone, so there's a limit to how good an overview we can get of whatever is going on. We didn't know the extent of the outbreak so we thought we'd play it safe. But we haven't been scared off, and the project will continue next summer", says Dorothee Ehrich. She pauses, then continues, "But we'll probably take some extra precautions."

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

Searching for environmental contaminants using UFOs

Environmental contaminants can travel with the wind from the equator to the Arctic, and the longer such contaminants survive in the environment, the greater their potential to cause unwanted effects on people, animals, and nature. Scientists from NILU have recently criss-crossed Norway, using "UFOs" to search for airborne organic contaminants.

In June 2016, PhD student Helene Lunder Halvorsen and scientist Ingjerd Sunde Krogseth, both from NILU - Norwegian Institute for Air Research, got into a rental car proudly labelled with the NILU logo in Kirkenes, and embarked on a mission to deploy 55 air samplers throughout Norway. Three months later, they set out to collect them again.

DRIFTING THROUGH THE AIR

The air samplers resemble UFOs; they are composed of two steel bowls, with a disc made of polyurethane foam in the middle. The disc acts as a filter, capturing semi-volatile organic compounds floating with the wind. The contaminants Helene and Ingjerd are particularly interested in capturing are known as POPs - persistent organic pollutants.

"POPs are a major global environmental problem", explains Helene. This is partly because they break down very slowly in the environment (are persistent), accumulate in organisms (bioaccumulate), inflict damage on health and/or environment (are toxic), and can be transported over long distances. Examples of POPs are PCBs, various types of brominated flame retardants, and pesticides like DDT.

"When these substances are released into the environment they can remain there for a long time", continues Ingjerd. "In addition, they can travel with the wind, ocean currents and rivers, but transport by air is the fastest way POPs travel from their sources to more remote areas such as Norway and the Arctic."

ENVIRONMENTAL CONTAMINANTS ALL OVER NORWAY

As long as the environmental contaminants remain in the air, they have little direct effect on animal and human health. However, once they are deposited on the ground or in the sea, they can be taken up by animals or fish and hence become part of the human food chain.

Not all sources of such contaminants are far away: some contaminants derive from local sources in Norway and the Nordic region. Helene wants to look into the relationship between the long-range transported contaminants and those from local sources during her doctoral work. This is knowledge that will benefit environmental authorities and policy makers when they consider whether local/national measures or international cooperation would be most effective to reduce the contaminant load.

The project is part of the programme *Ecosystem effects - natural responses to changes in climate and the environment* (ØKOSYSTEM), under the Research Council of Norway. In addition, a project funded by the Fram Centre's Hazardous Substances flagship programme has facilitated deployment of UFOs to several places in Svalbard.

NOT EXACTLY LAB CONDITIONS

Most of us think of scientists as white-clad people working in spotless laboratories.

"Not us", laughs Ingjerd. "We obviously had to be very careful not to transfer chemicals from the car or ourselves while storing, wrapping or unwrapping the samples and the sampling equipment, but lab coats just would not cut it. Think rather nitrile gloves, rubber boots and raingear!"

The rental car was bursting with everything they needed to take and store samples of air, soil, and moss. All the foam filters were wrapped in aluminium foil and double plastic bags to avoid contamination, and their portable cooler was used for storing air samples rather than food.

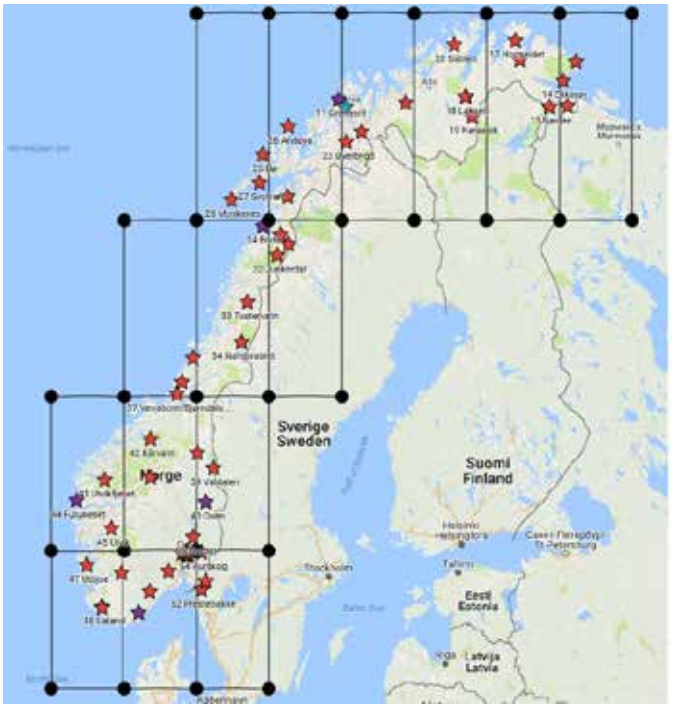
"An extension cord for the cooler was a must", Helene adds. "Without it, we would have had to sleep in the same room as the cooler at night, and it makes a lot more noise than you'd think!"

Other recommendations for their fellow scientists are to bring along both a GPS device and coordinates, which should be

When scientists Ingjerd Sunde Krogseth and Helene Lunder Halvorsen deploy air samplers for measuring environmental contaminants, it is important that they do not contaminate the samples. Thus, all equipment is packed in aluminium foil and double plastic bags; the scientists must use gloves, and they cannot wear sunscreen or mosquito spray. That can be quite a challenge during the Norwegian summer!
Photo: Christine F. Solbakken / NILU

Helene Lunder Halvorsen (left) and Ingjerd Sunde Krogseth posing with a UFO on a fish drying rack in Hamningberg on the Varanger peninsula.
Photo: Ingjerd S. Krogesth / NILU

A UFO with occupants at Furuneset. Fortunately for Helene and Ingjerd, this was not one of the UFOs they dealt with themselves, but assisting scientist Maja was startled when she opened it!
Photo: Helene Lunder Halvorsen / NILU



In total, 55 samples were collected all over Norway: ten from the Oslo area and three from each grid cell in the spatial model. These samples will be evaluated to test the model's ability to simulate the concentrations of organic contaminants actually observed in Norwegian air. *Map: NILU*

checked at least twice for accuracy before leaving. Besides that, cameras, wipes, and mosquito hats are necessities - the latter because mosquito spray may contaminate the samples.

PIECE OF CAKE

The UFOs were left to collect contaminants from the air for three months, so in late September it was time for another road trip.

This time they got help from senior scientist and project manager Knut Breivik. He started out in Kirkenes and stopped by NILU in Tromsø on the way before Ingjerd took over in Bodø. She drove through Trøndelag and the northwest of Norway down to Kjeller, where Helene took over. Crossing over the Stryne mountains to the west coast, she collected the UFOs along the coast to Egersund and then drove up to Kjeller again via Østfold. The samples from Oslo and Svalbard were collected the week before.

"It was much easier to collect them than to deploy them", says Ingjerd. "First, we had correct GPS coordinates for every sampler, and we didn't have to spend time finding spots for the UFOs that were as representative as possible, and at the same time unlikely to be contaminated by human activity in the area. In addition, all the soil and moss samples had already been taken, so in comparison, this trip was a piece of cake."

UFOS FROM ALL OVER EUROPE

All 55 UFOs on the Norwegian mainland were retrieved, and with few exceptions, they were all intact. Since the sampling is based on diffusion, the foam filter in the middle should under ideal conditions not be exposed to direct sunlight, rain or wind. However, in a few cases the lower bowl had slipped down so that the filter was visible. This may have affected the filter's uptake and the sample's validity. The same must be said about the sample from a UFO that had been almost completely filled by a wasps' nest!

Besides collecting samples in mainland Norway and Svalbard, Helene Lunder Halvorsen has completed a coordinated campaign in Europe. Altogether, she has sent out over 100 UFOs to air monitoring stations that are part of the European measurement network EMEP (European Monitoring and Evaluation Programme). All these have been returned by mail to NILU at Kjeller, where Helene and her colleagues have had their hands full sorting and storing the well-wrapped air samples in the freezer pending analysis in the laboratory.

"The analyses of samples from Europe will probably not be completed until after the summer", says Helene. "Then I will process all the results and make a distribution map across Europe and Norway. When we are finished, we will know far more about what kinds of environmental contaminants are present in the air over Norway and Europe, and where they come from. Over time, this could contribute to more effective measures for preventing these substances from getting into the environment. In addition, we will use the results to evaluate a model that we are developing to simulate variations in concentrations of contaminants in both time and space, with special consideration of Norway and the Arctic. This will help us understand more about the sources and transport of environmental contaminants. It will also let us know what we don't understand yet, and thus need to look into further."

Gunnar Sætra, Olav Sigurd Kjesbu and Jon Egil Skjæraasen // Institute of Marine Research

From “the welfare of the people” to scientific time series

Time series are crucial tools for environmental monitoring. The Institute of Marine Research, in cooperation with the University of Bergen, has developed what may well be the world’s longest biological time series – a 160-year record of liver size in northeast arctic cod.

Three fishermen photographed in Ballstad (1910), each with his own large skrei.
Photo: Norsk Folkemuseum, Anders B. Wilse

EACH YEAR THE NORTHEAST ARCTIC COD swims in from the Barents Sea towards the coast of northern Norway to spawn. The Lofoten Islands are among the best spawning grounds for the cod Norwegians call "skrei". The name comes from a word that means *to stride* and indicates that the cod wander over great distances. In Lofoten, the skrei practically come ashore during the spawning season, making them easily accessible for all types of vessels. For this reason, generations of fishermen from all along the coast have been coming to Lofoten to harvest this valuable resource.

STATISTICS

In 1859, Ketil Motzfeldt, then Inspector of Fisheries, began recording statistics on the turnover of liver and fish during the Lofoten fishing season. Several fishing regulations had recently disappeared following amendments to the Lofoten Act in 1857, and Motzfeldt started his registration for the "welfare" of the people whose livelihood came from fishing. Later, the statistics proved important for marine scientists, precisely because Motzfeldt registered both fish and liver. This was also the beginning of official fishery statistics in Norway, statistics that have been modernised on several occasions. At present, the Norwegian Fishermen's Sales Organisation (Råfisklaget) is responsible for ensuring that the skrei catches are registered and systematised. The organisation registers statistics on all white fish landed between Nordmøre and the Russian border.

HEPATOSOMATIC INDEX

Motzfeldt's registrations were never intended for anything but statistics. Johan Hjort, on the other hand, had more far-sighted goals. He was a pioneer of marine research and ultimately became the first director of the Institute of Marine Research (IMR). When he started up his own measurements of the relationship between the amount of liver and the amount of fish, his objectives were scientific. Hjort believed that the size of the fish's liver was indicative of its condition. Cod species store fat in the liver: a fatty liver tells us that the fish is in good condition whereas a low fat content means poorer condition. Hjort started his registrations in 1880 and continued until 1912. During these years, he gathered significant amounts of data about fish and their livers, which provided an important data point each year: a hepatosomatic index, that is to say, the total weight of liver divided by the total weight of fish. (Nowadays this is expressed as a percentage and is usually used to describe liver size of individual fish rather than group averages.) This index actually tells us something about the condition of the fish. The figures range from as low as 2-3% to as much as 15%. Fish with a high hepatosomatic index are in good shape, whereas a low hepatosomatic index indicates the opposite.

Two years after Hjort finished collecting fish and liver data, he published his seminal work, the groundbreaking treatise "Fluctuations in the great fisheries of northern Europe". It concluded about twenty years' work and documented for the first time that fish population sizes do in fact fluctuate naturally. At the time, natural fluctuations, as opposed to fishing, was the most important reason why catches varied from one period to another.

VARIOUS TYPES OF DATA WERE STANDARDISED

Johan Hjort's collection of fish and liver data is an important part of the time series developed in Bergen, showing the hepatosomatic index from 1859 to the present. The scientists have combined Hjort's time series with official fishery statistics – the statistics Motzfeldt started recording in 1859 and which are still being registered. They have also used data that are not dependent on fisheries, such as samples taken during the IMR's annual skrei expedition from the middle of March to early April. In addition, the scientists have used data from a time series for 1882 to 1928, compiled by Gunnar Rollefsen at IMR, in which he compared length and weight data for skrei. Samples taken from skrei catches delivered to the fish industry have also been included. This sampling started in 1932 and has continued up to today, apart from a hiatus in the 1970s.

Long and important time series

Access to time series is essential when scientists are painting scenarios for the future. Time series can be divided into two types: physical or biological. The longest of the former are meteorological, some of which date from the 16th century. Of the many time series in existence, one has attained "iconic status", namely the Keeling time series for CO_2, established in 1957 by Charles Keeling at the Scripps Institute of Oceanography. His measurements from Hawaii are invaluable in modern climate research.

Our longest hydrographic time series (measurements of salt content and temperature) are the "Kola Section" in the Barents Sea and the "Scripps Pier Time Series" from La Jolla, California. These started up in 1900 and 1916, respectively. The former provides monthly information on the top 200 m of the water column in a "section" (transect) from Kola and straight northwards into open waters (from 70°30'N, 33°30' E to 72°30'N, 33°30' E). The value of the Kola Section is doubled by the fact that it reflects not only temperature and salt content over time, but also the strength of the incoming North Atlantic Drift (the tail end of the Gulf Stream). The data from Scripps Pier, on the other hand, are extremely detailed and include several measurements each week. Both the Kola Section and the Scripps Pier series have led to a basic understanding of oceanographic processes, documented in innumerable journals.

When it comes to biological time series, Norway is uniquely placed in having three of the longest marine fisheries–biological data series in the world: one for northeast arctic cod ("skrei"), one for Norwegian spring-spawning herring, and one based on beach-seine catches on the south coast of Norway. The first two started up in 1900, the last one in 1919 and they have provided a basis for ground-breaking research.

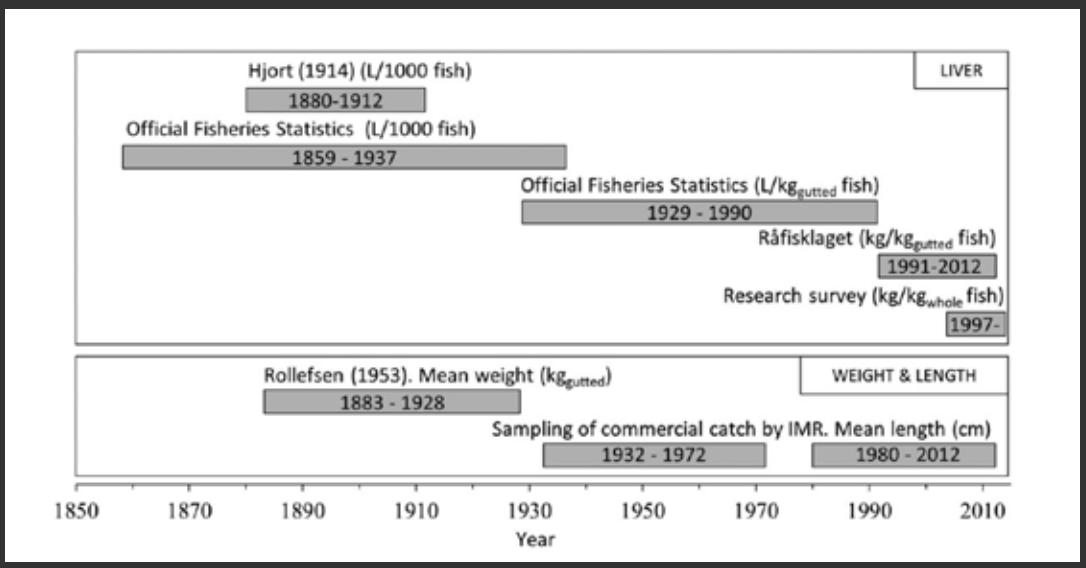
One recent result, for instance, shows that the current (record large) size of the skrei population, can be attributed to a combination of good fisheries management based on 50-60 years of close collaboration between Norway and Russia, and favourable climate over the past decade. The warmer climate has allowed the cod to expand its feeding area significantly; the population can now be found both at the far east and the far north of the Barents Sea. In the North Sea, the Norwegian Sea and the Barents Sea, research institutes now conduct regular "ecosystem cruises" which focus on ecosystem function and structure, in addition to calculating the size of individual populations.

The ecosystem cruise in the Barents Sea in the late summer/early autumn is especially important for studying changes at the more northerly latitudes. This cruise has had an interdisciplinary profile since 2004. Among other things, it has shown that arctic species are under pressure from more thermophilic species migrating in from areas further south.

Other ambitious cruise programmes have been set up for specific purposes; an example is the Mareano programme, which is mapping benthic habitats (see article on page 60). Among other things, this has contributed to 18 coral reef complexes along the Norwegian coast being defined as marine protection areas where trawling is prohibited. Passive fishing gear may be used, but the authorities are now in the process of implementing total protection in some areas. These are intended to serve as "reference areas" for studies of the effects of climate change.

Spawning skrei come very close to shore and can therefore be caught from all kinds of vessels, including these traditional boats manned by four or five rowers.
Photo: Norsk Folkemuseum, Anders B. Wilse

A haul of skrei delivered in Senjahopen.
Photo: Gunnar Sætra / Institute of Marine Research



Overview of data sources from the annual Lofoten cod fishery and research monitoring programme. Upper panel: Fisheries Statistics data on the relative amount of liver and fish, including the data from Hjort, presented either as litres of liver per thousand fish or litres of liver per kilo of gutted fish. The more recent Råfisklaget series reports kilos of liver per kilo of gutted fish, and the research survey data present kilos of liver per kilo of whole fish.
Lower panel: Supplementary data sources of information on gutted weight and length.

In order to make the nearly 160-year time series, the marine scientists had to coordinate and standardise the data from the various types of statistics, time series, and other methods of data collection. For example, the liver size in Motzfeldt's registrations and Hjort's time series was measured in litres of liver per 1 000 fish. Later, official statistics operated with litres of liver in proportion to gutted weight. Since 1991, the relationship is measured as kilos of liver per kilo of gutted fish. To obtain a standardised hepatosomatic index for the whole period, the scientists used mathematical models. In this way, the different data were coordinated and the result a time series that stretches from 1859 to the present. We now call this time series "Hjort's Hepatosomatic Index".

TEMPERATURE AND ACCESS TO FOOD

As mentioned above, the hepatosomatic index for skrei tells us whether the fish is in good shape or not. This may in turn say something about the natural conditions the skrei has lived in from year to year. For example, there are indications that the temperature in the sea affects the skrei's condition. We can see this if we compare the hepatosomatic index with another long time series, the so-called Kola Section. The Kola Section is a straight line on the map from the coast of Kola northwards into the Barents Sea. Russian marine scientists have measured the temperature and salinity of the sea along this section since 1900 (see page 40). When we compare findings from Hjort's hepatosomatic index with temperature measurements along the Kola Section, we see that the fluctuations in the hepatosomatic index have mainly followed the fluctuations in temperatures in the Barents Sea. In other words, the skrei's condition improved when the temperature rose, whereas it worsened in periods with falling temperature. Temperature and hepatosomatic index correlated well until a few years ago, when something changed and the hepatosomatic index went down at the same time as the temperature went up. This shows how difficult it can be to predict the consequences of global warming and highlights how important it is, for research, that long time series are not broken.

Even though there is a correlation between temperature and hepatosomatic index, we see that the skrei's access to food is a more significant factor than the temperature. During years with good food access, the index is higher than in years with little food. Capelin is one of the cod's "favourite dishes"; therefore the hepatosomatic index has also been high during years when the capelin population has been strong.

Karl Erik Karlsen (left) and Kjell Arne Gamst taking samples from skrei delivered to Axel I. Hansen in Senjahopen. General manager Frank Magne Hansen (right) watches with interest.
Photo: Gunnar Sætra / Institute of Marine Research

Marine biologist Ragni Olssøn shows off a skrei during the expedition of 2012.
Photo: Gunnar Sætra / Institute of Marine Research

HEPATOSOMATIC INDEX AND POLITICAL UNREST

In 1903, the hepatosomatic index was at an all-time low. History books and other sources relate that few skrei came to the coast that year. The fishermen perceived a "black sea", with very little fish. At that time, there was also extensive whaling along the coast of northern Norway. In Finnmark, the biggest whaling companies had built land stations to receive and process whales from the Barents Sea. The fishermen believed it was the whales that frightened the skrei towards shore. Therefore, they also believed that widespread whaling was to blame for the absence of skrei that year. In Mehamn, the animosity against whaling was so strong that the fishermen destroyed the whaling station. It would be an exaggeration to claim a link between Hjort's hepatosomatic index and political unrest, but the events of 1903 show that the skrei was (and is) an important factor in the financial well-being of northern Norway - and hence also a political factor.

Subsequent analyses indicate that the fishing crisis of 1903 was caused by the collapse of the capelin population. Lack of capelin also led to an invasion of seals along the coast because the Greenland seal in the Barents Sea could not find food in its ordinary feeding grounds. And the skrei were not doing well either, as is clear from the unique 160-year time series known as "Hjort's Hepatosomatic Index".

FURTHER READING:

Kjesbu OS, Opdal AF, Korsbrekke K, Devine JA, Skjæraasen JE (2014) Making use of Johan Hjort's "unknown" legacy: reconstruction of a 150-year coastal time-series on northeast Arctic cod *(Gadus morhua)* liver data reveals long-term trends in energy allocation patterns. ICES J. Mar. Sci. 71: 2053-2063, doi: 10.1093/icesjms/fsu030

http://icesjms.oxfordjournals.org/content/71/8/2053.full?sid=a2412387-efd3-4a09-b86c-fb96f9607fc2

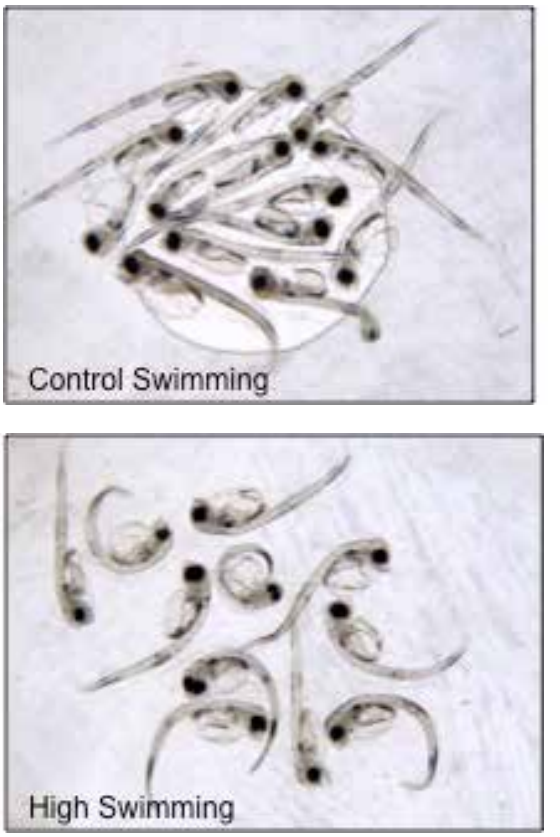
Karine Nigar Aarskog // UiT The Arctic University of Norway

Vulnerable to oil spills

The polar cod is common throughout the Arctic and is a major source of food for seals, whales and seabirds. Recent research shows that even small amounts of oil can affect the growth of this vital fish, and lead to deformities and death.

Young polar cod can often be seen swimming near sea ice in the Arctic. They find refuge from predators (seals and seabirds) within cracks in the ice.
Photo: Peter Leopold / UiT The Arctic University of Norway

Jasmine Nahrgang-Berge setting up the experiment with fertilised eggs of polar cod.
Photo: Jørgen Berge / UiT



Normal polar cod larvae (top) and larvae with malformations (bottom).

THE POLAR COD *(Boreogadus saida)* is a keystone species in arctic ecosystems, and is found in great numbers in the fjords around Svalbard. A study led by researchers at UiT The Arctic University of Norway shows that the eggs and larvae of the polar cod are more vulnerable to oil spills than previously believed - even when the amounts of oil are very small. These finding were published in the prestigious journal *Environmental Pollution* in November 2016.

"The levels used in the experiments were so low we were not able to measure them accurately in the laboratory", says Jasmine Nahrgang, assistant professor at UiT. "However, the fact that such tiny amounts of oil pollution give such clear results is in itself both astonishing and important", she adds.

EGGS UNDER THE ICE

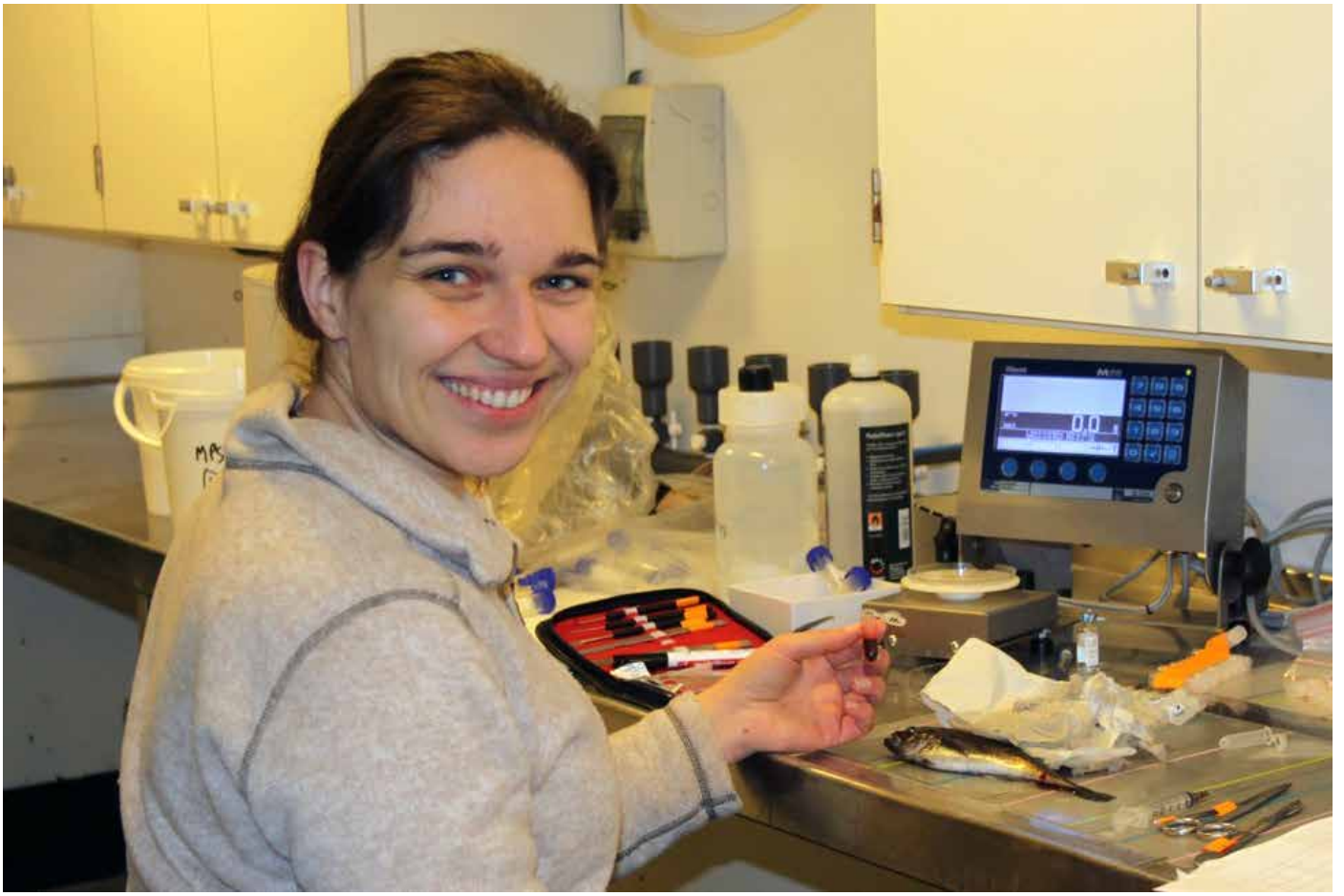
During January-March the polar cod spawns eggs that float up to the surface of the sea and if there is ice they settle just under it. This makes the polar cod highly vulnerable to oil spills in ice-covered waters. Even though scientists know that the polar cod is a species of great significance for ecosystems in the high north, very little experimental work has previously been done on the polar cod's eggs and larvae.

"This research is ground-breaking because previously very few people have managed to rear polar cod in captivity. We caught polar cod while on an expedition around Svalbard to study the polar night. We brought them to Tromsø and Kårvika where they stayed in tanks until they were ready to spawn a few weeks later", says Nahrgang.

Altogether, 12 000 eggs were used in the experiment.

"The experiments were carried out at the Marine Research Station at Kårvika over a period of 37 days. The eggs were fertilised in the laboratory and transferred to four different concentrations of oil: control, low, medium and high dose. The embryos were exposed throughout their development until hatching, and effects on larval growth and deformities were measured", Nahrgang explains.

The startling result is that even minute quantities of oil may hamper growth, cause deformities, and reduce the probability of larvae surviving.



Jasmine Nahrgang-Berge, lead scientist and in charge of the experimental design, dissecting a polar cod on board the research vessel *Helmer Hanssen. Photo: Jørgen Berge / UiT*

"We didn't see any direct mortality in the experiment", says Nahrgang. "The doses were so low that we didn't expect any mortality anyway, but the deformities and the reduced growth strongly suggested that the exposure would lead to higher mortality over time."

MORE HUMAN ACTIVITY IN THE ARCTIC

There are predictions that this year will see record low ice cover ice in the Arctic, which increases the potential for more activities in the north. At the same time, the Norwegian government recently opened new test fields for oil and gas exploration further north than ever before.

"It has often been said that the ecosystem in the Arctic is vulnerable, but our experiment really bears out this perception, as we see how small a dose is sufficient to affect growth and survival, and cause deformities of polar cod", says Nahrgang.

If there is an oil spill in frozen waters, the oil will probably be absorbed by the ice and then over time leak slowly into the water below.

"We know that the polar cod's eggs will naturally float around on the surface and just under the ice - precisely the places that will probably be most affected by the oil. The study is therefore not only ecologically relevant, but also environmentally relevant, and highlights connections we were not previously aware of", says Nahrgang.

IMPORTANT SPECIES

The polar cod is an important link in the food chain because it is specialised on eating arctic zooplankton. Moreover, even though the species above the polar cod in the food chain also eat other fish, especially in summer, polar cod is often the only available food in winter, when migrating fish move south.

Mature polar cod about to be stripped of their eggs prior to the experiment (left), and the gonads of a mature male (above). *Photos: Jasmine Nahrgang-Berge / UiT*

Summing up the project, Jasmine Nahrgang says, "This research shows that even small oil spills in the Arctic may be extremely significant, especially locally. Given that the polar cod is a keystone species in the system, its extreme sensitivity to oil pollution shows that even small spills may have dramatic consequences for the entire ecosystem."

FURTHER READING:

Nahrgang J, Dubourg P, Frantzen M, Storch D, Dahlke F, Meador JP (2016) Early life stages of an arctic keystone species *(Boreogadus saida)* show high sensitivity to a water-soluble fraction of crude oil. Environmental Pollution 218, 605-614, http://dx.doi.org/10.1016/j.envpol.2016.07.044

Sabrina Tartu and Heli Routti // Norwegian Polar Institute
Sophie Bourgeon // UiT The Arctic University of Norway

Fat matters when sea ice melts: polar bears, pollutants and sea ice decline

While most of us have declared war on fat, the layer of fat beneath our skin is vital. Fat cells store energy in the form of lipids. In addition to being the body's largest energy supplier, these cells secrete hormones that control whether we feel hungry. Arctic animals also need fat as insulation.

POLAR BEARS MOSTLY FEED ON SEAL BLUBBER. In spring and early summer, when seals lie hauled out on the ice, polar bears can eat so much that 50% of their body weight can be pure fat. Polar bears need these huge fat stores to survive long periods without food. For example, pregnant females fast from the ice-free late summer/autumn and through an entire winter, spending up to 8 months in the den where they give birth and nurse their cubs.

Polar bears feed at the top of the arctic marine food web. That exposes them to a number of environmental pollutants, which are transported from industrialised areas to the Arctic by air and ocean currents, and then biomagnify in food webs. Consequently, pollutants can reach toxic concentrations in these top predators.

STORING FAT IN A POLLUTED, CHANGING WORLD

During the last decades, with the simultaneous increase of chemical use and (human) obesity, several teams of researchers have investigated potential links between chemicals and the onset of obesity. *Obesogens* are chemicals that can disrupt how the body stores and uses fat (lipid metabolism). Several chemicals found in the environment appear able to provoke insulin resistance, for example, leading to diabetes and obesity.

The polar bears in the Barents Sea are among the bears in the Arctic that carry the highest concentrations of environmental pollutants. They also face the threat of ongoing climate change. Polar bears use sea ice to breed and feed, but with global warming, Arctic Sea ice is shrinking and thinning. Lack of sea ice makes it difficult for bears to find their preferred food and fatten up. They thus lose weight and become thinner, which may exacerbate the hazardous effects of pollutants.

HOW DO SEA ICE, POLLUTANTS, AND FAT INTERACT?

Two projects, one funded by the Research Council of Norway and the other by Fram Centre's Hazardous Substances flagship, both led by Heli Routti from the Norwegian Polar Institute, brought together a team of national and international researchers to study the combined effects of sea ice decline and pollutant exposure on fat metabolism, in polar bears from Svalbard.

Lack of sea ice makes it difficult for bears to hunt seals.
Photo: Magnus Andersen / Norwegian Polar Institute

We took samples from female polar bears during two contrasting seasons: spring, when sea ice is at its maximum extent, and autumn, when most sea ice has melted.
Photo: Magnus Andersen and Heli Routti / Norwegian Polar Institute

We captured female polar bears during two contrasting seasons: spring, when sea ice reaches its greatest extent, and autumn, when sea ice is at its minimum. The sampling years also provided contrasts, with more sea ice in the winter of 2012 than in 2013. Finally, the sampling areas differed, as there is less sea ice year-round west of Svalbard than east of Svalbard.

We measured several notorious legacy pollutants (including organochlorine pesticides, PCBs and degradation products) and several emerging pollutants (such as per- and polyfluoroalkyl substances (PFASs) and brominated flame retardants). Since PCBs, pesticides and flame retardants are lipid-soluble, we measured them in both fat and blood. In contrast, as PFASs and PCB metabolites bind to proteins, such as those circulating in blood, we measured them only in blood. We examined whether pollutant levels were related to sea ice conditions, which differed between seasons, years, and areas.

We also compared pollutant levels in female polar bears that were with or without cubs, thin or fat, fasting or not. Our main finding was that the concentrations of lipid-soluble pollutants in polar bears were higher when sea ice was scarce. Then the bears were thinner and pollutants were more concentrated, whereas in fatter bears the pollutants were more diluted.

PERTURBED FAT METABOLISM IN POLAR BEARS

We related pollutant concentrations to health indicators that signal potential disruption of fat metabolism. Specifically, we measured the expression of genes involved in fat metabolism, thyroid hormone concentrations, and clinical parameters (e.g. cholesterol, triglycerides). In addition, we isolated stem cells from polar bear fat. We used them in the laboratory to test whether pollutant mixtures affect stem cells' accumulation of fat. We also built an assay to test whether pollutants can disturb receptors in the cell nucleus that switch on and off a range of genes involved in fat metabolism.

Fat and blood samples are used to study pollutants and their health effects in polar bears.
Photos: Heli Routti and Magnus Andersen / Norwegian Polar Institute

We found that pollutant concentrations were related to the expression of genes involved in lipid storage and breakdown, and in cholesterol synthesis. In addition, bears that were more exposed to PFAS had higher cholesterol concentrations. Thyroid hormones regulate an animal's metabolism by regulating the "functioning speed" of its organs to be in line with its needs. Relationships between thyroid hormones and pollutants suggested that polar bears with heavy PFAS, PCB, and pesticide loads might have an inappropriate metabolism and consequently burn less energy than they need. Although the consequences of this are unknown, it could possibly reduce their production of body heat - a requirement for survival in their cold environment.

The results of the Bear Energy project converge in a unanimous description of disrupted fat metabolism in female polar bears from Svalbard. Furthermore, these results are internally consistent. For example, the down-regulated metabolism revealed by lower concentrations of thyroid hormones would lead to the increased triglyceride levels we observed in blood, as the organs would not consume enough of the circulating energy. In addition, our laboratory experiments on polar bear stem cells and cellular receptors indicated that pollutants do indeed perturb fat metabolism in polar bears.

EFFECTS ARE WORSE WHEN SEA ICE MELTS

When considering sea ice conditions, we observed stronger correlations between pollutants and markers of fat metabolism when conditions were extreme, for example during the exceptional iceless winter of 2013. This means that very warm temperatures, such as those recently recorded in Svalbard, are likely to exacerbate the perturbing effect of pollutants on fat metabolism in polar bears.

Stepan Boitsov, Bjørn Einar Grøsvik and Jarle Klungsøyr // Institute of Marine Research

Decreased or stabilised levels of contaminants in Norwegian waters

Twenty years of environmental surveys show that contaminant levels in open waters are slowly but surely decreasing for some groups of substances, and continuing at stable low levels for others. A recent report from the Institute of Marine Research shows lower levels in the north than in the south.

Ear stones (otoliths) are used to determine the age of fish.
Photo: Gunnar Sætra / Institute of Marine Research

Fish are among Norway's most important resources and clean waters are a prerequisite for good, sustainable management. Unfortunately, human activities over the last few centuries have had an adverse effect on all parts of the environment, including the ocean. This is where a large number of chemicals used for various purposes end up. If we are to grasp the scope of the problem, we must know what types of pollution exist, where, and how much. The surveying programme of the Institute of Marine Research has been running for more than 20 years in the North Sea, the Norwegian Sea, and the Barents Sea. We have gathered extensive data about man-made contaminants in fish (16 species) and crustaceans (three species).

MONITORED SUBSTANCES

Among many hundreds of chemicals identified as contaminants, we have chosen to focus on chlorinated contaminants (such as PCB and some pesticides), in fish and crustaceans. These substances are industrially produced and decompose slowly in nature. This is why traces of them remain in the environment even many years after their release. They are among the most harmful chemicals released into the environment. The potential to cause damage varies from substance to substance: some of them may be hormone disruptors or have carcinogenic effects; others may be acutely toxic even in small concentrations. The United States prohibited production of PCB in 1979, and PCB was later included with several pesticides in the list of persistent contaminants prohibited by the Stockholm Convention in 2001.

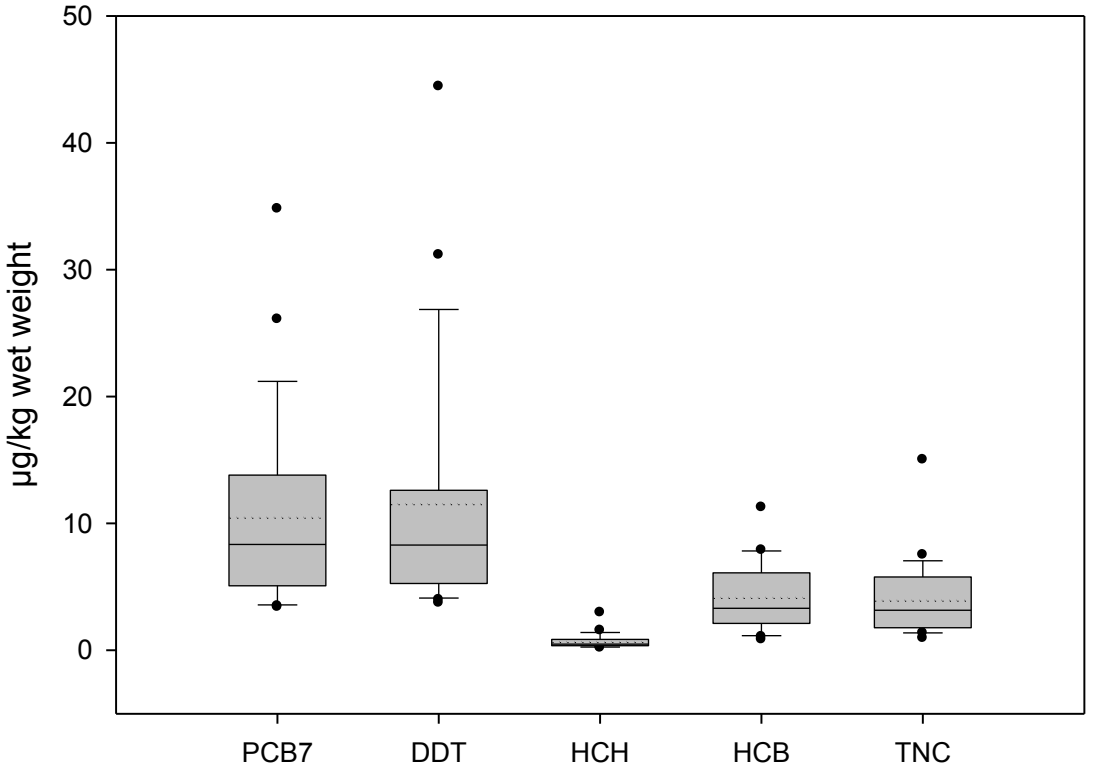
Other groups of contaminants are also included in our surveys. These substances are different from chlorinated contaminants and require a separate analysis. We also analyse brominated flame retardants, which have not been used for as long as PCB but also decompose slowly and represent an environmental problem because they are so widespread. They are widely used all over the world as additives to technical equipment, furniture, textiles, and other household goods, as they are efficient at preventing fire. Some types of brominated flame retardants are also on the list of substances that are to be phased out pursuant to the Stockholm Convention.

Another important group of substances is polycyclic aromatic hydrocarbons (PAHs), which can come from a variety of sources and also occur naturally in the environment. PAHs form during combustion of organic material and are given off in smoke (for instance in exhaust from cars, burning coal, and wood). They are also found in oil and other fossil fuels. Fish are able to excrete these contaminants quite efficiently - at least in small amounts - but crustaceans do not have the same enzyme system for metabolism and excretion of PAHs. PAHs can also accumulate in sediments. Our project therefore analyses sediments from the seabed to examine PAH levels there.

THE STOCKHOLM CONVENTION

The Stockholm Convention on Persistent Organic Pollutants is a global treaty against environmental contaminants that remain intact in the environment for long periods, are globally distributed, accumulate in living organisms, and have harmful impact on health.

The Convention was adopted in 2001 and entered into force in 2004. It prohibits the production and use of certain environmental contaminants. To begin with, the Convention listed 12 environmental contaminants, among them PCB, DDT and HCB. The list has later been expanded with additional substances, including some of the brominated flame retardant compounds. At the end of last year, 180 countries had ratified the Stockholm Convention.



Chlorinated contaminants in liver of long rough dab from the Barents Sea (sampled in 2009). The average level for 24 fish is shown by a dotted line. The solid line in the middle shows the median level. The boxes enclose 50% of the data, the whiskers show the limits of 80% of the data and dots represent individuals with observed contaminant levels above or below that. Contaminant levels are relatively low overall, though some individuals have high levels of PCB7 and DDT. The amount of HCH is very low in all the fish.

LEVELS IN THE OCEAN TODAY

Our results from 20 years of environmental surveys vary quite a lot. Levels of some types of contaminants are low or undetectable, whereas others are clearly present. We see, for instance, low levels of brominated flame retardants, while there often are higher levels of PCB and the pesticide DDT than of other substances. The higher we get in the food chain, the greater the concentrations of contaminants. This is as we expected. Concentrations also increase with age in fish. Generally speaking, the highest levels are found in the North Sea (especially near the coast and in Skagerrak) and the lowest levels in the Barents Sea, but large variations have also been observed.

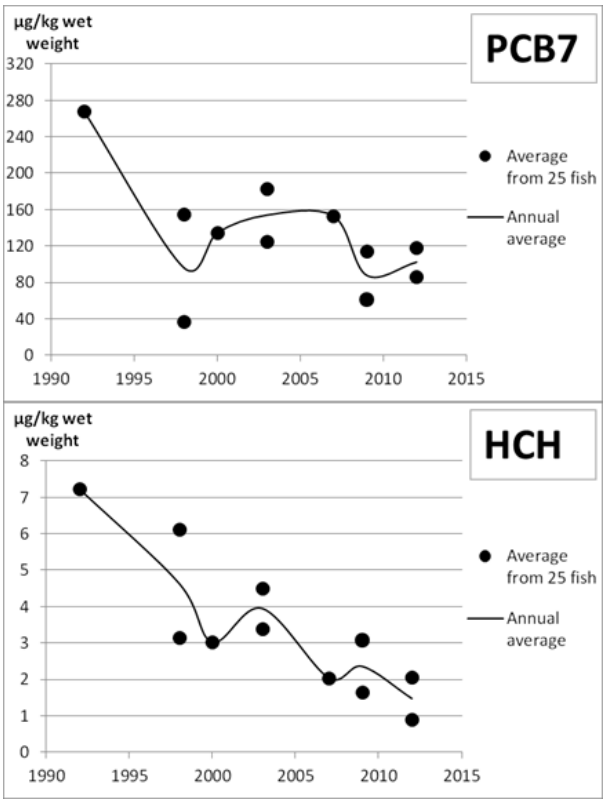
Although some of the contaminants are present at higher concentrations than others, even the higher levels are usually below the maximum limits for nutritional safety (200 g/kg wet weight for the sum of six PCB congeners in liver). However, individual fish may on occasion deviate markedly from the average (see figure).

SOME DECREASE FOUND

Several species have been sampled consistently over time, whereas others have been sampled more sporadically. For the species under regular surveillance, we can present time series describing changes in the contaminants over time. Levels of some substances have decreased significantly in the past 15-20 years. An example is the pesticide HCH in liver from cod in the Barents Sea. Levels of some other substances seem relatively stable, for instance PCB in liver from the same cod.

Our surveys show that it is still important to monitor organic contaminants in the marine food chain and in sediment. The contaminants are transported over great distances from their original sources, and background levels are clearly detectable even in the Arctic, where there are few local pollution sources. Despite having been prohibited for several decades in many countries, some of these contaminants persist in the environment.

For some groups of substances, levels in open waters are slowly but surely decreasing, while others are maintaining stable low levels. It is important to document this development, too, and thus continue the time series established through two decades of surveys.



Contaminants in livers from Barents Sea cod. Data for each year represent averages from 25 fish. Levels of PCB7 decreased rapidly, then stabilised from the end of the 1990s, whereas the levels of the pesticide HCH showed relatively steady decrease throughout the study period.

CHLORINATED ENVIRONMENTAL CONTAMINANTS

Polychlorinated biphenyls (PCBs)
PCB28
PCB52
PCB101
PCB118
PCB138
PCB153
PCB180
PCBs include 209 chemical compounds that differ only through the position of their chlorine atoms. This list presents only the seven that are most frequently measured.
Uses: additives in electrical equipment, paint, building materials

Chlorinated pesticides
DDT (dichlorodiphenyltrichloroethane)
p,p'-DDT
p,p'-DDE
p,p'-DDD
Uses: insecticides

HCH (Hexachlorocyclohexane)
α-HCH
β-HCH
γ–HCH (lindane)
Uses: insecticides

HCB (hexachlorobenzene)
Uses: fungicides

TNC (*trans*-nonachlor)
Uses: component of the insecticide chlordane

FURTHER READING (IN NORWEGIAN ONLY):

Boitsov S, Grøsvik BE, Nesje G, Tveit G, Klungsøyr J (2016) Undersøkelser av organiske miljøgifter i fisk, skalldyr og sedimenter fra norske havområder de siste 20 årene. Institute of Marine Research. Report no 29-2016

Available online at www.imr.no/filarkiv/2016/10/rapport_nr_29-2016_sb.pdf/nb-no

Karine Nigar Aarskog // UiT The Arctic University of Norway

The blue mussels around Svalbard have come a long way

When mussels were discovered alive and well on Spitsbergen in 2004, it was a sensation, as blue mussels had been absent since the time of the Vikings. Closer study shows that some of the mussels found in Svalbard today come all the way from the Mediterranean. This astonishes scientists.

"THE MARINE ECOSYSTEM up here in the north is constantly exposed to a natural invasion from the south. This is mainly because the northern part of the Gulf Stream system flows into our waters and keeps Svalbard's fjords warm and ice-free through the long, cold winter", says Jørgen Berge, professor of biology at UiT The Arctic University of Norway.

The warm water also brings living organisms from the south, such as the heat-loving, southern species *Mytilus galloprovincialis*, or the Mediterranean mussel.

"Ever since the first marine biologists started to examine our waters we have been aware of this influx of species, but it was a huge surprise for us to find that some mussels could come from as far south as the Mediterranean", says Berge.

The sensational finding was recently published in *Evolutionary Applications* after the UiT professor, in collaboration with colleagues from Greece and Russia, charted the arctic populations of mussels. The project received support from the Fram Centre Flagship programme Fjord and Coast.

NEW MUSSELS AND NEW METHODS

The first observation of living mussels in Svalbard was made in 2004 at Sagaskjæret furthest out in Isfjorden. Since then, scientists have found mussels in several places in both Isfjorden and Kongsfjorden.

"Even the first time we observed mussels at Sagaskjæret, we assumed that this was a result of small larvae being transported northwards and into Isfjorden via the Gulf Stream system. We thought they came from the closest site, which means from the area around Lofoten", says Berge.

At that time, genetic studies indicated that it was the common mussel, *Mytilus edulis*, that had spread northwards from northern Norway. However, the scientists

Live mussels from Bykaia in Longyearbyen. Even though they all look alike, new studies show that these are probably individuals with genetic material from two or three different species. *Photo: Peter Leopold / UiT The Arctic University of Norway*

had insufficient data to draw firm conclusions. Now, more than ten years later, new mussel finds give them an opportunity for more exhaustive study.

"Using better data and new genetic methods, we are now able to determine where the mussels in Svalbard actually come from, and - not least - determine conclusively whether or not they belong to the species *Mytilus edulis* - the common mussel", says Berge.

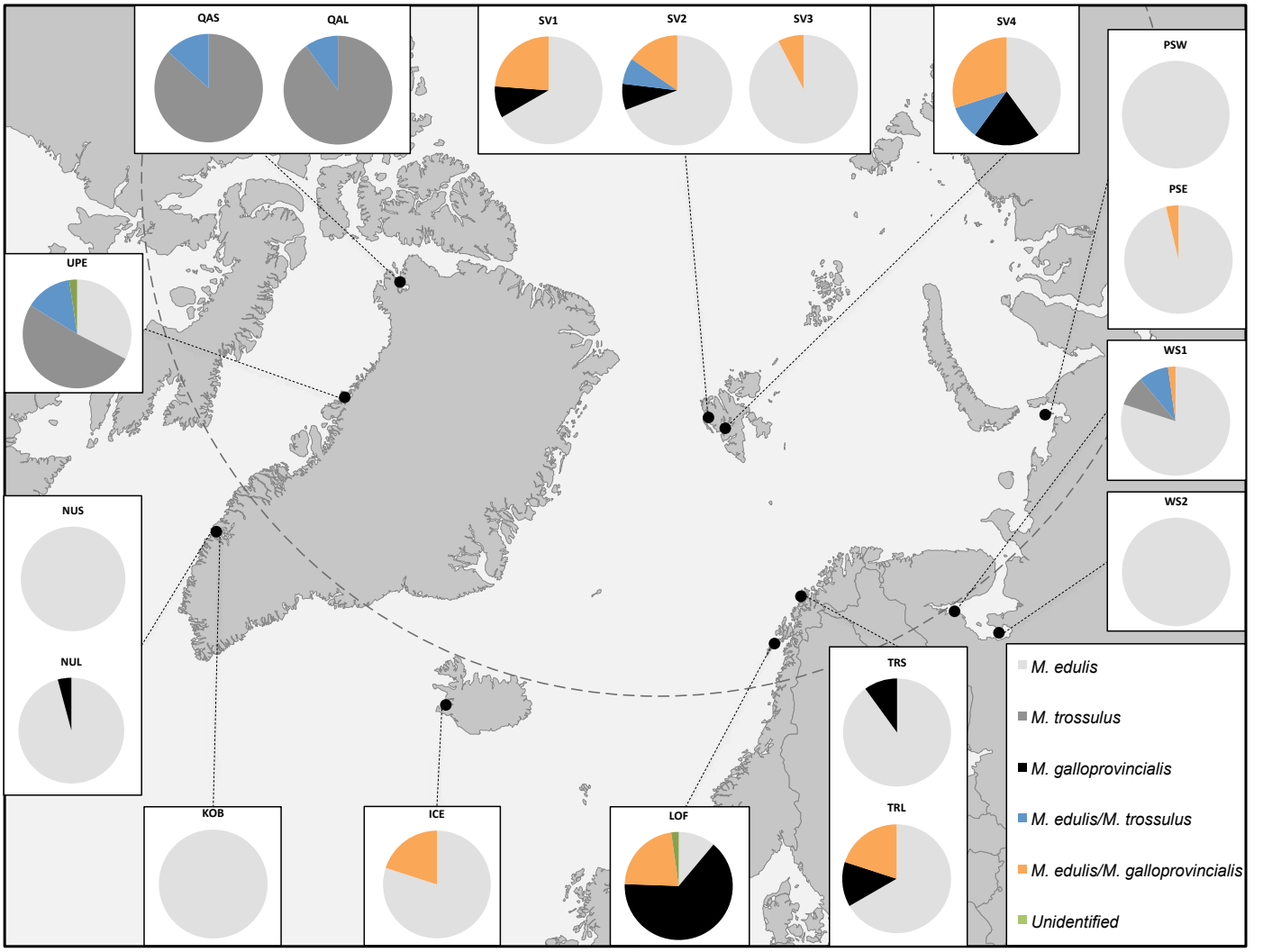
RELICS FROM THE PREVIOUS ICE AGE?

In fact, several alternatives to the "Gulf Stream" hypothesis have been proposed. Some scientists have claimed that the mussels found in the Arctic are ancient but previously undiscovered populations of mussels from North America - more specifically, the species called *Mytilus trossulus*. According to this hypothesis, they must have lived in Svalbard continuously since the last Ice Age, without being discovered. Other scientists have claimed that the mussels did not come to Svalbard through natural dispersion but rather as a consequence of shipping.

"So we gathered material from as many areas of the Arctic as possible, including Greenland, northern Norway, Svalbard, and the White Sea. Even though the relevant species of mussels are extremely similar on the outside and practically impossible to tell apart if they live in the same place, they have genetic markers that allow us to tell them apart relatively easily by studying their DNA", explains Peter Leopold, a PhD student at UiT. "Genetic markers will also be able to tell us if any of these mussels are hybrids, that is, a mixture of species."

MUSSEL HYBRIDS

The scientists' data show that the mussels found in Svalbard are not relic populations of the North American species but mainly carry the genetic material of the common North Atlantic mussel *Mytilus edulis*. The



Species distrubution of different types of mussels in Greenland, Svalbard, Iceland, northern Norway and Russia.

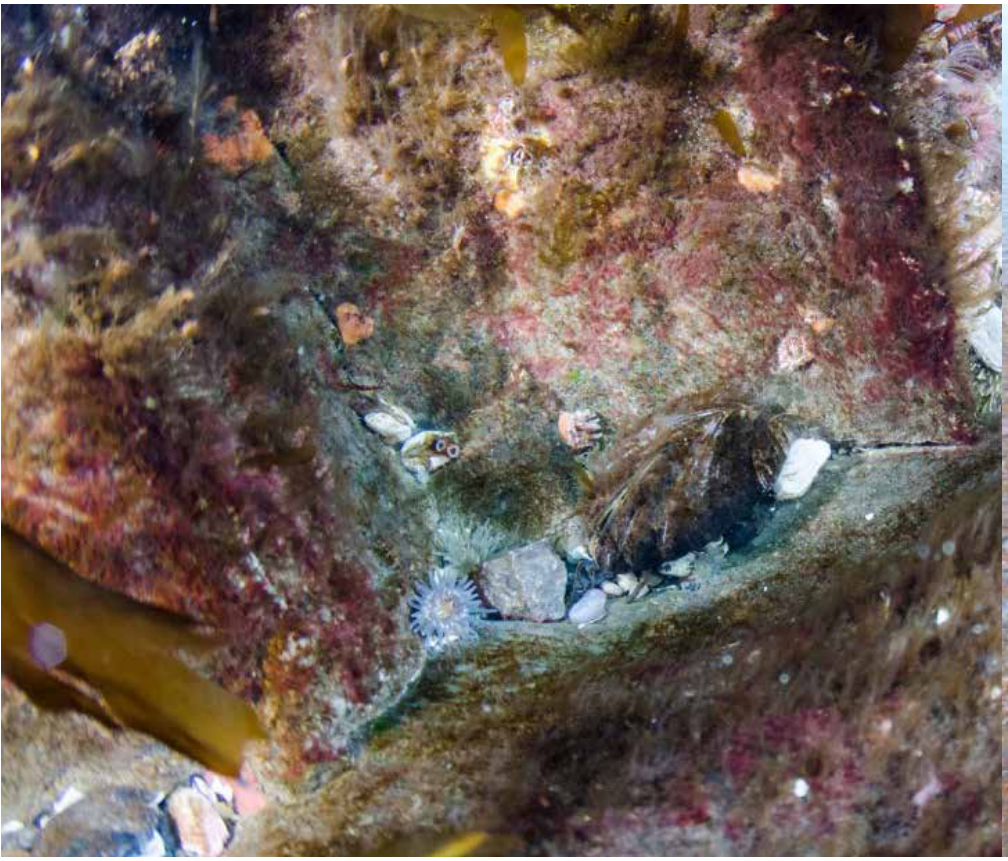
North American species was common mainly along the west coast of Greenland, which agrees with the earlier assumptions; mussels were a new species in Svalbard when they were discovered in 2004. However, a significant amount of genetic material from the Mediterranean was also found in all the populations examined. Only the populations taken from the more isolated areas of the White Sea and the coast of Greenland had a genetic structure where one of the three species was completely dominant. The others consisted of a mixture of species, with elements from the Mediterranean.

"It's important to emphasise that we are not talking about a mixture of separate species (individuals living side by side), but a mixture of genetic material: hybrids or crossings of the three species. This means we're not seeing a situation where different species come drifting in with the sea currents separately, but that they have probably come north gradually and in a manner that allows genetic mixing", says Leopold.

The findings also refute the possibility of sporadic dispersion via shipping, since the genetic composition is fundamentally similar between separate populations in different fjords on Svalbard.

WHAT IS A NATURAL CONDITION?

Berge believes that the charting of mussels allows important questions concerning an administrative regime of Svalbard, which takes as its starting point



The mussels in Svalbard are often difficult to spot, well hidden among seaweed, bryozoans, hydrozoans and other organisms. This photo is from the area in which the mussels were first seen in 2004, Sagaskjæret at the mouth of Isfjorden.
Photo: Peter Leopold / UiT The Arctic University of Norway

Fossil shells from Rijpfjorden in Svalbard. Mussels lived in Svalbard in warm periods after the last Ice Age, but which species lived here then? It has not been possible to isolate DNA from these fossils.
Photo: Colin Griffiths / SAMS

conserving or preserving nature in its "natural" condition.

"What is actually natural when it is so obvious that we don't even know which species live in more or less untouched areas of the Arctic?" he asks. "How do we manage a sea area that during our lifetime is going through enormous changes, both natural and man-made?"

He also believes that the findings indicate another important point: that it can be difficult to draw up clear boundaries in nature.

"A politically defined wolf zone makes as little sense to a ranging wolf as to a mussel larva caught in a sea current on its way north, regardless of whether it carries hereditary material from southern latitudes or not. Svalbard is, has always been, and always will be a hotchpotch of organisms with different backgrounds, and as temperatures, ice, and other important factors change, the marine system will also respond more or less immediately", Berge concludes.

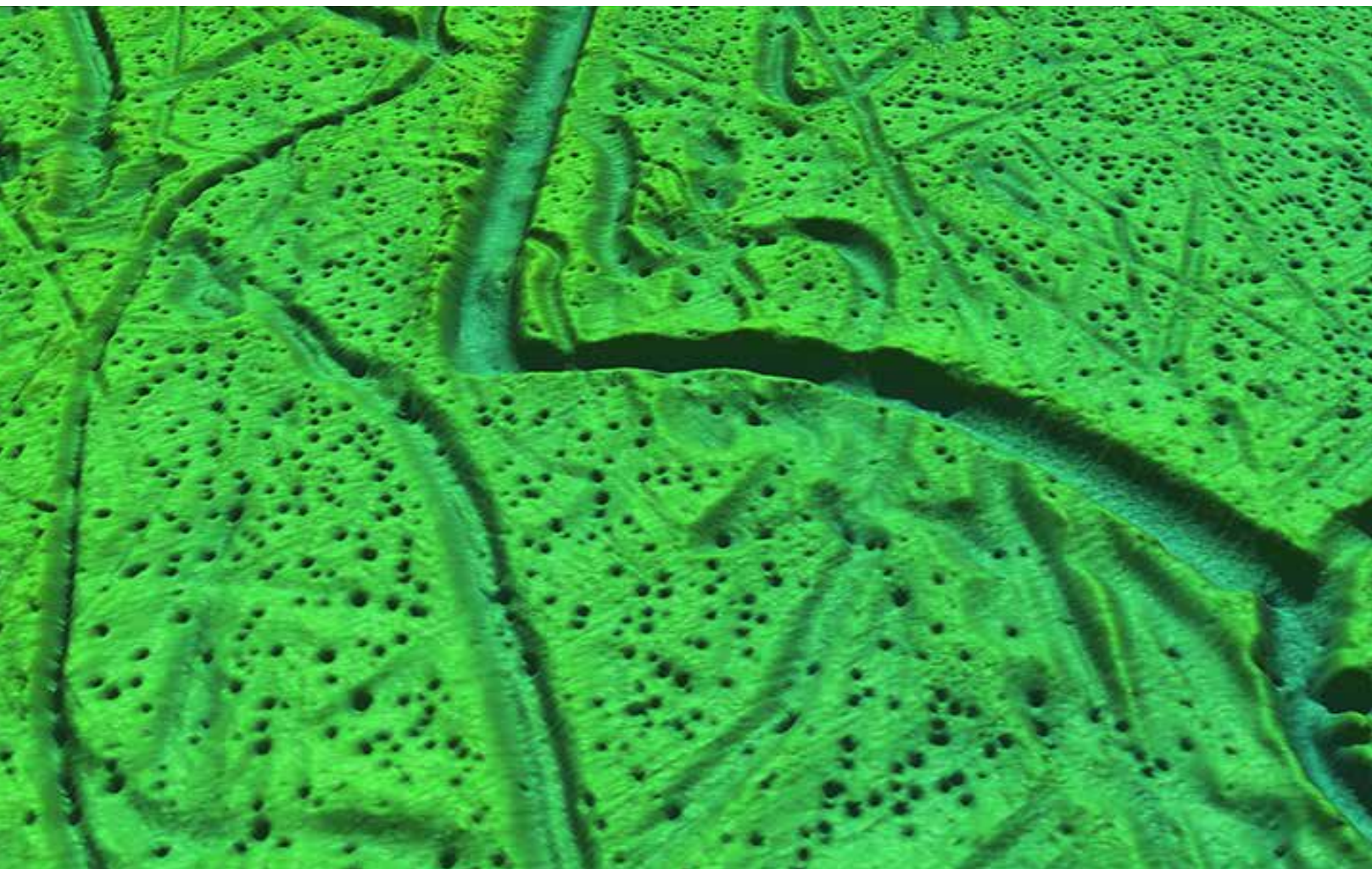
FURTHER READING:

Mathiesen SS, Thyrring J, Hemmer-Hansen J, Berge J, Sukhotin A, Leopold P, Bekaert M, Sejr MK, Nielsen EE (2016) Genetic diversity and connectivity within *Mytilus spp.* in the subarctic and Arctic. Evol. Appl. 10: 39-55, doi: 10.1111/eva.12415

Børge Holte and Gunnar Sætra // Institute of Marine Research

Benthic fauna may give warning of changes in the environment

The seabed holds a rich diversity of animals big and small. If you look closely at a handful of sand and sludge from the seabed and it will change from a dull grey mass to a writhing, hopping world of crustaceans, mussels and polychaetes. These tiny creatures may help us answer important questions.

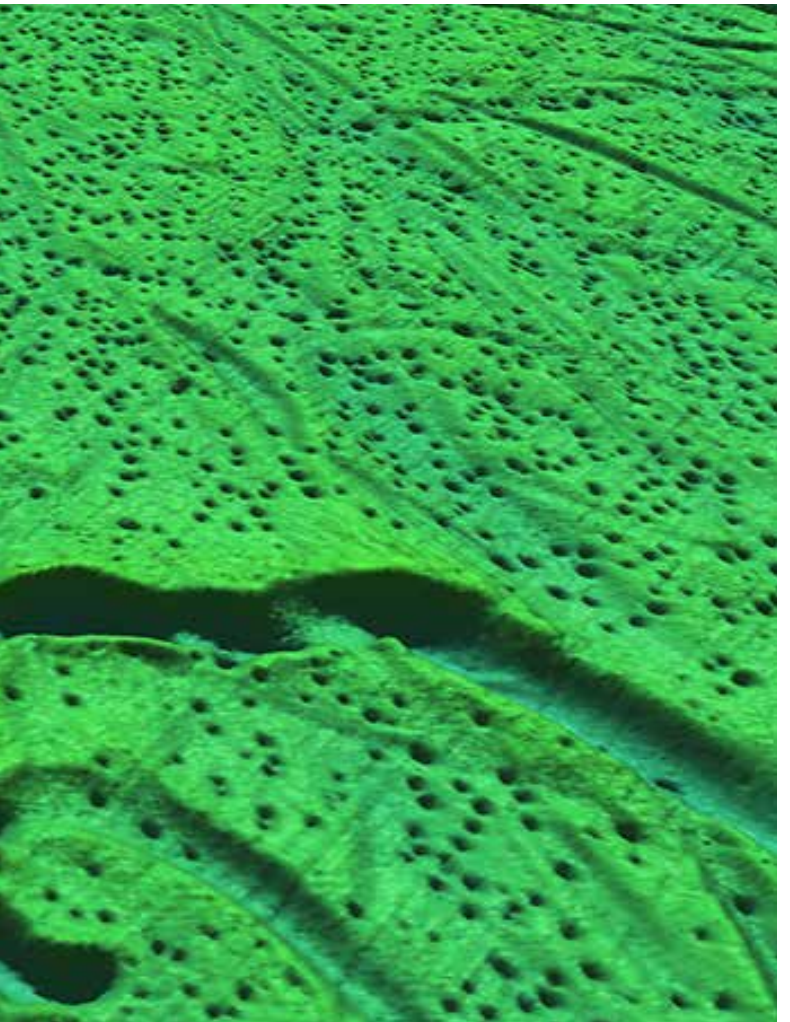


Nature's own artwork at 260 metres depth in the Barents Sea. Using icebergs as pens, sea currents have sketched neat patterns into the seabed over the course of hundreds of years. The glacial groove in the middle of this computer-generated image is 140-150 metres wide and 8-10 metres deep. The dots in the picture are "pockmarks" made by gases or fluids forcing their way up through the seabed. Pockmarks are common in much of the Barents Sea. *Image: Norwegian Mapping Authority/Mareano*

If you grab a handful of sediment from the seabed, you may actually be holding dozens of species big enough to see with your own eyes. If you use a magnifying glass, pocket lens or microscope you will see even more. The animal world on the sea bottom is among the world's most diverse per unit area. These benthic communities may give warning of climate changes and other factors that influence the environment.

BENTHIC CREATURES CANNOT ESCAPE

The large number of species normally found on the seabed means that benthic communities are well suited for measuring the seriousness of any changes in environmental conditions. Some species are sensitive to certain environmental changes and can disappear, whereas other species tolerate the changed conditions better. In this way, new species are able to take over dominance of a locality. Such changes in a community's species structure can be proven mathematically and quantified.



It is possible to use benthic communities as a measurement tool for trends in the environment because the animals are essentially stuck in the seabed, or can move only short distances. By contrast, fish, marine mammals, and several other species can go elsewhere if faced with environmental changes they dislike or cannot tolerate. Benthic fauna cannot escape. Therefore, some species die when the temperature changes, whereas other species proliferate.

Human activity also affects the seabed: fishing gear such as trawls leave tracks and change the benthic fauna's physical living conditions. Mining waste spilled into the sea changes the seabed; the same may be true of extraction of oil and gas. Indeed, benthic animals are already being used to measure any influence around offshore installations. It is important to map the seabed before starting such activities, so it is possible to find out which changes follow from fisheries, mineral extraction or petroleum activities. Such baseline mapping is taking place in the Mareano project.

WHICH AREAS ARE BEING MAPPED?

Mareano (acronym for Marine areal database for Norwegian waters) is a collaboration between the Institute of Marine Research, the Norwegian Mapping Authority and the Geological Survey of Norway (NGU). One of the reasons for starting the project was to generate data on diverse biotopes to be used in future management of Norwegian seas, as well as following up on the objectives of the UN's Earth Summit (held in Rio de Janeiro in 1992) concerning ecologically holistic management of the natural environment.

The areas being mapped by Mareano have been carefully selected to include fish spawning grounds, areas with high biological productivity, fishing grounds, the marginal ice zone in the Barents Sea, and the transition area between arctic and subarctic water masses (the polar front). Phytoplankton productivity at the edge of the sea ice is especially high because as the ice melts and retreats northward, nutrients become available for algal blooming and sunlight penetrates into the water column.

Mapping of coral reefs is a high priority. The coral in question (*Lophelia pertusa*) grows very slowly, only a few millimetres per year, and is therefore

Both the reef-forming coral (*Lophelia pertusa* (left)) and the deep sea seapen (*Umbellula encrinus*, right) are vulnerable species. They grow very slowly and stick up out of the seabed and can therefore easily be damaged by e.g. fishing gear. It may take several decades for the deep sea seapen to attain its maximum height of up to 2 metres. Coral reefs need several hundred years to reestablish after damage. Note the tiny tentacles of each individual coral polyp. *Photos: Pål Buhl-Mortensen / Institute of Marine Research/Mareano*

particularly vulnerable to damage by fishing gear. These reefs provide shelter and nutrition for scores of benthic animal species and fish, and are known to harbour rich biodiversity. Unlike tropical coral reefs, cold-water reefs grow in relatively deep waters and at low temperatures (4–9°C). There are several thousand coral reefs on the Norwegian continental shelf, especially in areas like the edge of the slope, where seabed currents transport food particles and supply the coral polyps with sustenance. The Røst Reef, the world's largest known cold-water reef, shows that the conditions in Norwegian coastal waters are favourable for the growth of corals. The Røst Reef complex is as much as 35 kilometres long and 2.8 kilometres wide. On Mareano's website, the Institute of Marine Research presents running updates about registered occurrences of corals in Norwegian waters.

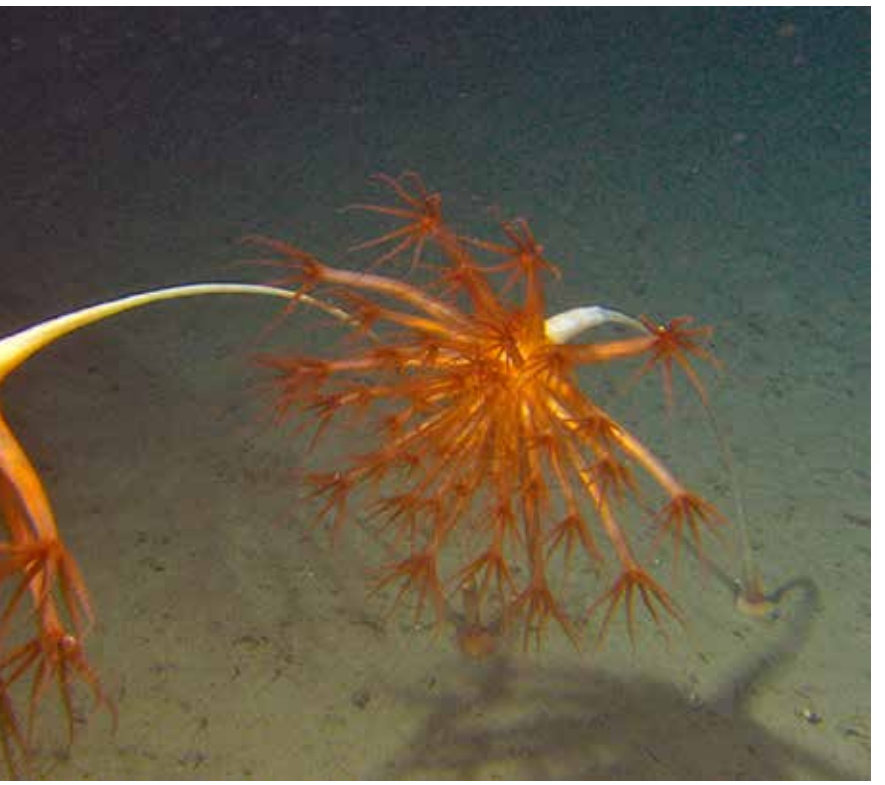
COMPREHENSIVE SAMPLING

Mareano uses vessels belonging to the Institute of Marine Research to map the seabed. We gather sediment samples with different types of tools such as grab, sled and beam trawls, and use video cameras to film the seabed and what lives there. In addition, we use modern multi-beam echo sounders. With this information, we can construct various types of maps, including computer-modelled biotopes.

From a global perspective, the Mareano Project is one of the most comprehensive of its kind. After 10 years, including 3½ years at sea, we have filled more than 4 000 pails and buckets with bottom samples, published two books and about 60 internationally peer reviewed papers, and registered 2 415 different species and taxa of macro- and megafauna. (In this context "macro" means larger than 1 mm and "mega" larger than 5 cm.) Scientists from Norway and abroad, who have borrowed material from Mareano's fauna collection at the University Museum of Bergen, have described some ten species that are new to science, and several other unknown species are next in line.

SEVEN-LEAGUE STEPS IN THE RIGHT DIRECTION

One of the objectives from the Rio Conference is to ensure sufficient knowledge about ecosystems to predict the effects of human activities on nature. This



After research cruises, sampled fauna specimens are examined under a microscope to identify species-specific characteristics; their wet weight (biomass) is measured, and they are catalogued at the University Museum of Bergen. *Photo: Institute of Marine Research/Mareano*

is the key to holistic and sustainable management - that is, ecosystem-based management - of marine resources. In this way, instead of being caught off guard by unforeseen negative effects, we can take preventive measures. Effective prevention may often make human activities justifiable. Commercial fishing is an example: the harvest of fish is compensated by biological monitoring and a controlled by a strictly enforced quota system.

The effects of ongoing climate change are apparent in northern waters. Higher temperatures have been registered in the Barents Sea over the last decades. Climate effects have been detected in shallow benthic fauna communities near Svalbard, and the geographical range of several fish species has expanded into arctic waters east of Svalbard.

It is therefore more important than ever to follow up the objectives of the Rio Convention regarding knowledge-based, sustainable management - both to be able to implement preventive measures in untouched sea areas, and to implement measures in waters that have already suffered negative effects. The Mareano Project represents a seven-league step towards achieving this objective. We combine skilled experts and modern technology such as video recordings, measurements with multi-beam echo sounders, computer visualisation and modelling, electron microscopy, DNA sequencing and other tools. The unique multidisciplinary collaboration adds weight to Mareano's mapping and provides commercial stakeholders, scientists, environmental managers and others with new knowledge. Mareano gives a voice to the benthic fauna and lets them tell us what is happening below the surface of the ocean.

Mar Fernández-Méndez, Lasse Mork Olsen, Hanna M. Kauko, Haakon Hop* and Philipp Assmy //
Norwegian Polar Institute

The Arctic Ocean's invisible forest in times of rapid climate change

The frozen Arctic Ocean looks like a cold, white, inhospitable desert, yet seals, whales and polar bears appear there sporadically. The presence of large marine mammals tells us there must be an invisible forest below the ice, producing the food they need to survive. In 2015, we explored that forest.

DURING THE NORWEGIAN young sea drift expedition (N-ICE2015), when the research vessel *Lance* was frozen into the ice north of Svalbard, we studied the ocean's invisible forest as the sun returned to the Arctic in spring after the long dark winter. The ice around us was our backyard and we took samples every day to discover how the complex ecosystem works. Excitement spread among the biologists when in late May, despite the thick snow cover, the water and the ice started to turn brownish-green. The invisible forest was beginning to flourish.

Microscopic single-celled algae growing on and inside the sea ice (ice algae), and in the underlying water (phytoplankton), form the invisible forest of the Arctic Ocean and constitute the production base of its ecosystem. The herbivores that eat them are small crustaceans that fuel the ice-associated ecosystem, from polar cod to polar bears. We humans rely on fish as an important source of protein and oils (lipids) in our diet, and as the sea ice retreats further north, commercial vessels have started to fish in arctic waters. Factors that control algal productivity may determine whether the future Arctic Ocean will become a new food basket. With sea ice getting thinner, younger and more dynamic, and snow precipitation increasing due to climate change, the future arctic ice-scape will surely be different. During N-ICE2015, we had a unique opportunity to study the new ice regime during spring 2015 and were able to get a "sneak preview" of how the future seasonal ice zone may look.

SLIMY *PHAEOCYSTIS* RULES THE WATER COLUMN

On 25 May, the water turned green. We were suddenly in the middle of a massive phytoplankton bloom

*Haakan Hop is also affiliated with UiT The Arctic University of Norway

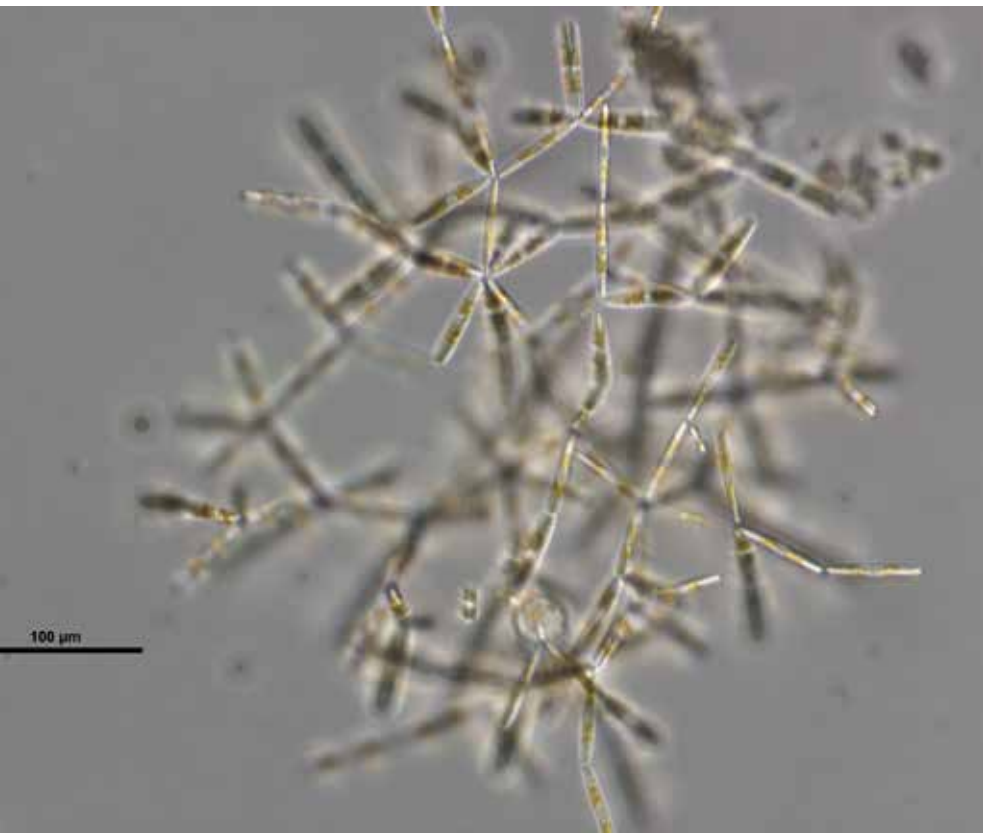
Sampling the optical properties of the water column through a hole in the thin ice of the refrozen lead. *Photo: Alexey Pavlov / Norwegian Polar Institute*

growing below sea ice that was covered by thick snow (40 cm), allowing very little light to penetrate into the underlying water column. This came as a surprise to us, as previously observed under-ice blooms in the Canadian Arctic had formed much later in the season, and below transparent sea ice with no snow and many melt ponds. During N-ICE2015, however, the answer lay in the leads. Studying satellite images, we detected many leads opening up during early spring. This promoted light transmission through the otherwise opaque ice pack and triggered the early phytoplankton under-ice bloom. These conditions favoured growth of the slimy phytoplankton species, *Phaeocystis pouchetii*, at the expense of pelagic diatoms, such as *Thalassiosira spp.*, *Fragilariopsis oceanica* or *Chaetoceros socialis*, which usually dominate the arctic spring bloom. Shifts in species dominance could have important implications for the fate of the fixed

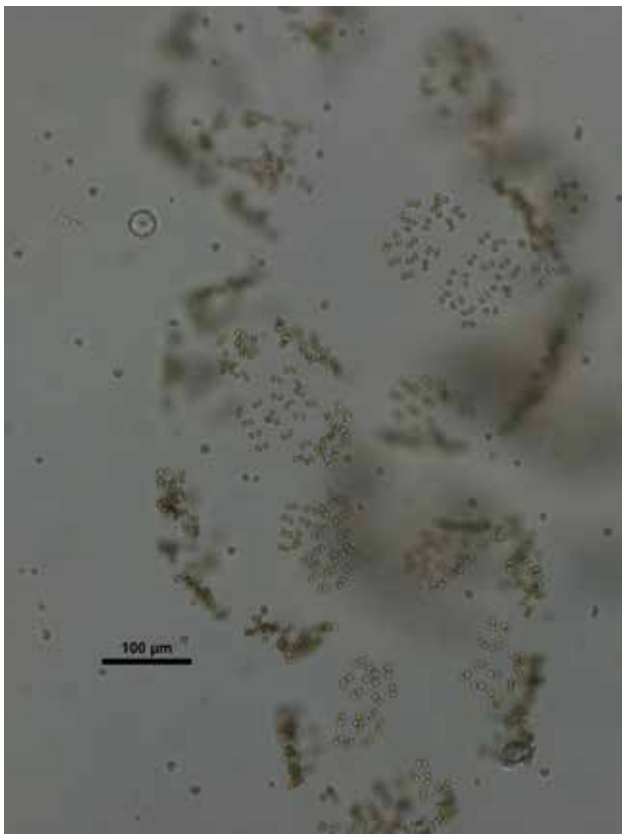
During the N-ICE2015 drift expedition, from January to June 2015, RV *Lance* was moored to four ice floes northwest of Svalbard and drifted with the pack ice for a total of 141 days. The aim of this multidisciplinary expedition was to understand the effects of the new arctic sea ice regime on energy flux, ice dynamics and the ice-associated ecosystem, by employing a suite of physical, chemical and biological measurements. The expedition began in the dead of the polar night and continued through the progression of spring.

More information: www.npolar.no/n-ice2015

FURTHER READING: https://eos.org/project-updates/arctic-research-on-thin-ice-consequences-of-arctic-sea-ice-loss



Ice that survives the summer melt acts as an algal seed bank. *Nitzschia frigida* resides there during the winter and seeds the ice algal bloom in new ice in spring.
Photo: Philipp Assmy / Norwegian Polar Institute



Under-ice bloom dominated by *Phaeocystis pouchetii*.
Photo: Philipp Assmy / Norwegian Polar Institute

carbon as *Phaeocystis* is not relished by the dominant grazers (*Calanus* copepods) and does not sink to the deep ocean.

SUNSCREEN ON THIN ICE

From early May until early June, we had a unique opportunity to follow the progression of a thin-ice environment in a refrozen lead that had formed next to RV *Lance*. This allowed us to study in detail how leads act as windows into the ocean. Not only did the phytoplankton bloom profit, but also ice algae took advantage of the high light transmission through the thin lead ice and formed a small ice-algal bloom. These ice algae had the highest concentrations of mycosporine-like amino acids (MAAs) ever recorded in sea ice. MAAs are water-soluble molecules that absorb ultraviolet (UV) radiation and act like sunscreen against damaging UV levels. On the other hand, the energy-demanding production of MAAs might have slowed algal growth, reducing the magnitude of the bloom.

OLD ICE: AN ALGAL SEED BANK IN WINTER

Next to thin young ice, we also sampled older ice, mainly second-year ice. The detailed time-series enabled us to identify how the life cycles of a dominant ice algal species are geared to the sea-ice environment. The diatom *Nitzschia frigida* is the champion of the sea ice invisible forest, but how this species adapts to the ice melt season and winter is still unknown. According to our observations, ice that survives the summer melt season acts as a repository for *N. frigida* that will serve as the seed bank for next year's spring bloom of ice algae when the sun returns. However, if

Navicula sp. with sunglasses and sunscreen tube with MAAs.
Credit: Mar Fernández-Méndez / Norwegian Polar Institute

Mar Fernández-Méndez (left) and Hanna Kauko sampling the snow-ice interface.
Photo: Marcel Nicolaus

conditions in the future Arctic Ocean mean that less ice survives the summer, this seed bank will progressively disappear, threatening the long-term survival of ice-associated species like *Nitzschia frigida*.

ANTARCTIFICATION OF ARCTIC ICE ECOSYSTEMS

In June, the sea ice started to melt from below. As the thick snow pushed the ice under the water surface, the ice became flooded with seawater. In particular, cracks in the ice enabled algae from the water column to infiltrate the snow-ice interface. We got very excited about the rich brownish-green soup below the snow, but even more interesting was that the algal species growing there were pelagic diatoms, including *Thalassiosira* species and *Fragilariopsis oceanica*! Yes, exactly the ones that were outcompeted below the ice by *Phaeocystis pouchetii*. They seemed to be doing fine at the snow-ice interface, closer to the light, where they were protected from grazers and replenished with nutrients. These types of communities are known from the Antarctic, but have rarely been observed in the Arctic.

Changes in the Arctic ice-scape are happening fast and our new observations indicate that we must constantly update our knowledge in order to make predictions about the future arctic ecosystem. Thus, it is crucial to continue performing research expeditions to the white desert to unveil the secrets of its invisible forest.

Ole Magnus Rapp

Innovative research sheds light on marine life during the polar night

For years no one believed that there was much activity in the Arctic Ocean during the polar night, but recent discoveries show that it is teeming with life, from small zooplankton to fish and seabirds. Moonlight is enough to affect the life forms in icy waters during the winter.

The students steer the submarine robot and monitor what it sees on their screens. From the left: Roland Pfeiffer, Lisa Winberg von Friesen, Pauline Wischhusen and Johanna Thorbjørnsen.
Photo: Ole Magnus Rapp

A helmet jellyfish came slowly drifting into the harbour in Ny-Ålesund. The species has never before been observed in Svalbard. *Photo: Geir Johnsen / Norwegian University of Science and Technology*

DURING THE PAST FEW WINTERS, various experiments have been done in Kongsfjorden on Spitsbergen to study marine life in the dark polar night. This year's experiments have employed four unique submarine vessels as well as an advanced automated kayak that registers everything from small algae to seabed, from fish to temperatures.

Biologists collaborate closely with technologists, and robots provide answers to questions that scientists have pondered for a long time.

PITCH DARK AND COLD ALL THE TIME

This year, about 30 scientists, technicians, and students from eight countries took part in the research, with Ny-Ålesund as their base. At least as many experts were on board the research vessel *Helmer Hansen*, which stayed near edge of the sea ice at about 82°N.

"It's fantastic to be able to collaborate with the people who are developing the robots", says Susanna T. Thorbjørnsen from the University of Agder, who is taking a PhD in marine coastal ecology. After a fortnight in Ny-Ålesund, where they spent a lot of the time out in boats gathering various samples, the students continued to the University Centre in Svalbard (UNIS) in Longyearbyen, to evaluate their finds.

Thorbjørnsen came more or less straight from field studies in Australia, experiencing a difference in temperature of 50°C. Nonetheless, she smiles in the boat as she and the other students scrutinise their screens to see what the robot is filming on the seabed. Some steer the submarine drone, while others read off data.

"You quickly forget the cold", says Thorbjørnsen. "This is exciting!" She watches closely as tiny snails cling to a kelp stalk.

LONG-STANDING COLLABORATION

Biology professors Jørgen Berge from UiT The Arctic University of Norway, and Geir Johnsen from the Norwegian University of Science and Technology (NTNU), are both associated with UNIS and have collaborated for a long time. For several years now, they have led research cruises north of Svalbard during the polar night, and their findings are creating a stir all over the world.

"There is hectic life in the ocean, even in the darkest period. Light from the moon, among other things, affects the organisms, and there is a lot of research still to be done", says Jørgen Berge.

Berge and Johnsen have a habit of discovering new species during their stays in Svalbard. Back in 2004,

Maarja Krussmaa (right), an Estonian professor of robot technology, collaborates closely with biology professors Geir Johnsen (left) and Jørgen Berge to discover all the life forms that are active in the ocean during the polar night.
Photo: Ole Magnus Rapp

they found mussels, a species that has been absent from Svalbard since the Viking Age. Mackerel, atlantic redfish, herring, capelin, and cod are moving northwards and becoming more common in Isfjorden and Kongsfjorden, which have both been ice-free during winter for the last ten years.

ANOTHER NEW DISCOVERY

This year a new species appeared, to the complete surprise of the scientists. With their colleague Sanna Majaneva from UiT, Berge and Johnsen were out on the quay to look at life in the ocean. Into their cone of light came two helmet jellyfish, a species that dominates a few fjords on the Norwegian west coast, but had never previously been seen in Svalbard.

“These are really big jellyfish that eat krill and small fish. They cause problems in Norwegian fjords and it will be interesting to see what they lead to in Svalbard”, says Jørgen Berge. The jellyfish were visible to the naked eye, but many discoveries are made by new robots fitted with special sensors.

ADVANCED EQUIPMENT

Professor Martin Ludvigsen at the Department of Marine Technology at NTNU has been instrumental in developing the submarine drone “Blueye”, which has four engines and can manoeuver down to depths of 100 metres. On the way, it films and photographs everything around it, and afterwards the scientists can identify all the minute species it passed by.

“This is a prototype. We are right at the start, and things are developing quickly”, says Ludvigsen. A designated company has been formed to sell the robot commercially and the testing in Svalbard is providing the inventers with useful experience.

The converted kayak “Jetyak” is packed full of electronics. A side-scanning sonar can chart the seabed while an acoustic zoo-plotter registers plankton in the entire water column. The Jetyak has a camera that can see birds in the dark, and the vessel can send images continuously via broadband radio.

“There is only one of these things in the whole world, and we are privileged to be part of its development”, says Petter Norgren, a PhD student at NTNU.

“For us technologists, collaborating with biologists is very stimulating. Together we find good solutions”, says Pedro de la Torre, engineer at NTNU, who is project coordinator for a comprehensive new research project north of Svalbard that is starting up now.

Biology professors Geir Johnsen (left) from NTNU and Jørgen Berge from UiT are leading sensational research in Svalbard. They have arrived at the conclusion that there is teeming life in icy waters, even in the darkest polar night. *Photo: Ole Magnus Rapp*

New technology is tested to study life in icy waters in the polar night. This robot, Blueye, is able to operate down to a depth of 100 metres and register even miniscule organisms. *Photo: Ole Magnus Rapp*

RESEARCH SUPPORT AND INFRASTRUCTURE

This winter activity is also important for the research village of New-Ålesund and Kings Bay AS, the company that owns it. Their livelihood comes from facilitating research, but things usually get pretty quiet here in the middle of winter.

“Being able to contribute to ground-breaking research is of great interest to us. We offer the scientists what they need in terms of logistics, and we collaborate well”, says Kings Bay Director Ole Øiseth.

The biologists appreciate the rich assortment of knowledge and the infrastructure that this special research community has to offer.

“Hugely proficient engineers and smart students help bring new knowledge into our research”, says Jørgen Berge. “The blend of experts we achieve here is very exciting.”

Heidi Ahonen, Kit M. Kovacs and Christian Lydersen // Norwegian Polar Institute

The soundscape where Spitsbergen's Critically Endangered bowhead whales breed

Sound travels through water across vastly greater ranges than light, and many marine organisms have evolved to exploit this fact. For many marine mammals, hearing is the primary sense; they use sound not just for communication and social interactions, but also for navigation and feeding.

MAN-MADE NOISE IN THE WORLD'S OCEANS is already a significant pollutant in some regions; it is affecting the behaviour and physiology of acoustically sensitive animals. Compared to other oceans of the world, arctic waters have been relatively free of anthropogenic underwater noise because for much of the year, extensive sea ice has restricted commercial access to the Arctic. In fact, at present, the dominant noise source in arctic waters is sea ice itself. However, as the Arctic is warming and sea ice is declining markedly, the arctic soundscape is changing. This is taking place partly through increased wind noise and new sounds emitted by temperate species moving northwards, but the greatest change in the future is expected to be increased noise from ships and from the host of industries that are already expressing interest in expanding into marine environments in the Arctic.

LISTENING UNDERWATER

Due to the importance of sound to marine life, acoustic characterisation and monitoring of marine environments is becoming a major focus for researchers and environmental managers. Considerable evidence suggests that arctic cetaceans (narwhals, bowhead and white whales) may be especially sensitive to the impacts of anthropogenic noise. Bowhead whales communicate with each other over vast distances using sound. Narwhals and white whales use echolocation signals to find their food as well as using other sounds for coordination and communication within their tightly knit social groups. Our research project (Arctic Cetaceans and Ocean Noise - ACON) in the FRAM Centre's MIKON programme, is using passive acoustic monitoring (PAM) technology to characterise the soundscape of the Norwegian Arctic and explore the potential impacts of anthropogenic noise on these vulnerable high arctic species. In general, PAM technology utilises autonomous hydrophones (underwater microphones) that can be deployed on a wide array of

A bowhead whale at the surface. Bowhead whales are the only baleen whales that reside throughout their lives in the Arctic. Their heavy, compact bodies aid in energy conservation, and their elevated nostrils allow them to breathe in waters with slush and ice.

Photo: Jon Aars // Norwegian Polar Institute

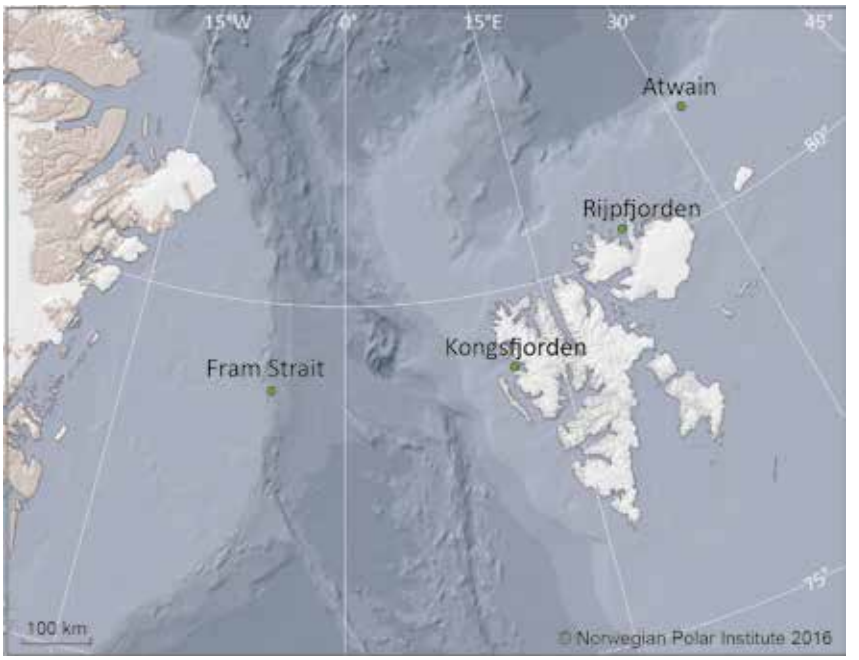
platforms (e.g. towed arrays, ocean gliders and moorings). In our case, the underwater sound recorders are attached to oceanographic moorings that sample a variety of oceanographic properties of the water column. Our AURAL (Autonomous Underwater Recorder for Acoustic Listening) recorders detect acoustic signals (both natural and man-made) throughout the year and provide long-term information about the underwater world of the Arctic. Currently, we have four recorders situated in both offshore and inshore environments in the northern Barents Sea region.

One of our recorders has been situated in Fram Strait, between Greenland and Svalbard, since 2008. This area has proven to be a core-use area for the Critically Endangered Spitsbergen bowhead whale population during their winter breeding period. Bowhead whales are vocally active year-round, but during the breeding season, they sing particularly complex songs. Given the projected increase in human activity in the northern Barents Region, the importance of Fram Strait area for Spitsbergen's bowhead whales, and the sensitivity of this species to human-generated underwater noises, we decided to explore the soundscape of Fram Strait to determine the overlap of bowhead whales and human activity (e.g. seismic surveys and shipping).

The soundscape of the region includes marine mammal sounds, seismic airgun signals, and occasional shipping noise, in addition to sounds generated by natural physical processes such as movement of ice and wind. The mean noise level is currently low to moderate (<60 dB) compared to other ocean regions, but during the ice-free season, overall noise levels increase by up to 20 dB (roughly 4 times as loud) due to physical processes such as wind and current.

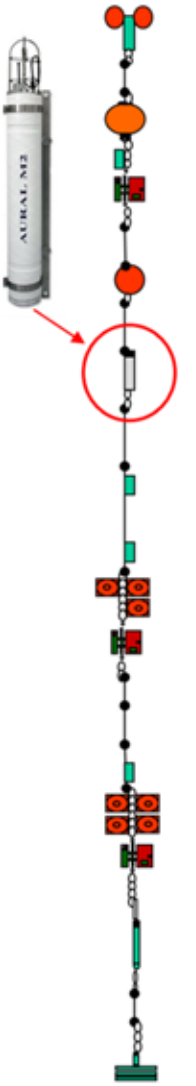
NATURAL SOUNDS

Our recordings demonstrated the presence of bowhead whales from October to July with singing occurring almost constantly in the period November to March. This near-constant singing identifies the Fram Strait as a vitally important habitat for Spitsbergen bowhead whales.



The Norwegian Polar Institute (and partners) AURAL network – locations of passive acoustics monitoring devices.

Map: Norwegian Polar Institute



Oceanographic mooring with the AURAL location shown.

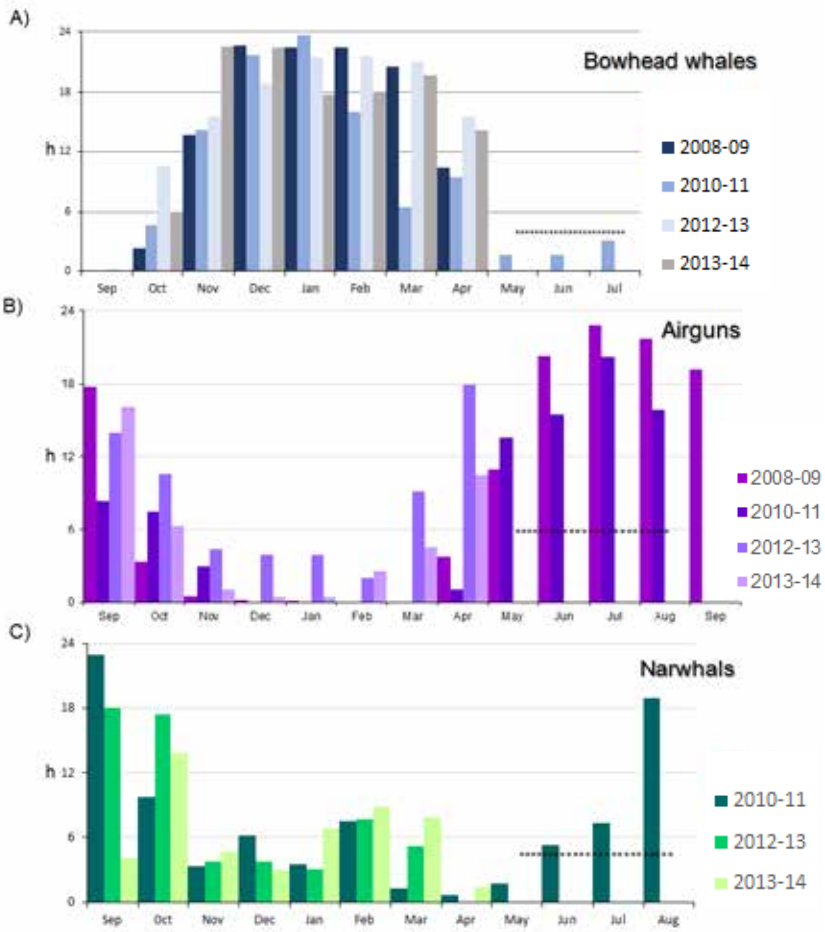
Diagram: Norwegian Polar Institute

Acoustic signals from other marine mammals were also detected by the Fram Strait AURAL. Narwhal vocalisations and echolocation clicks were recorded almost year round, suggesting that the area is also important for this endemic arctic cetacean. During the spring-summer months, bearded seal vocalisations were detected, and blue whale calls were recorded over summer and autumn months. Interestingly, fin whale 20 Hz (low frequency) pulse calls were recorded from September to March. These calls likely originate from singing performed hundreds of kilometres away, but they are nonetheless a component of the soundscape in Fram Strait.

MAN-MADE SOUNDS

Seismic airgun signals were detected throughout the year, peaking in the open water season in summer and autumn. Most of the signals were faint; they likely originate from distant seismic surveys (possibly >1000 kms away). These distant signals do not significantly increase the observed noise levels in Fram Strait, but some very loud airgun signals were also recorded, that are derived from seismic survey vessels operating within 100 km of the recorder. These operations increased the noise levels eightfold.

Although current human activity is relatively low in Fram Strait, there is some overlap between presence of arctic cetaceans and anthropogenic noise pollution. Climate change and concomitant reductions in sea ice are reducing the natural habitat of ice-dependent species and in the future are likely to expose them to increased anthropogenic noise pollution unless specific safeguards are set in place.

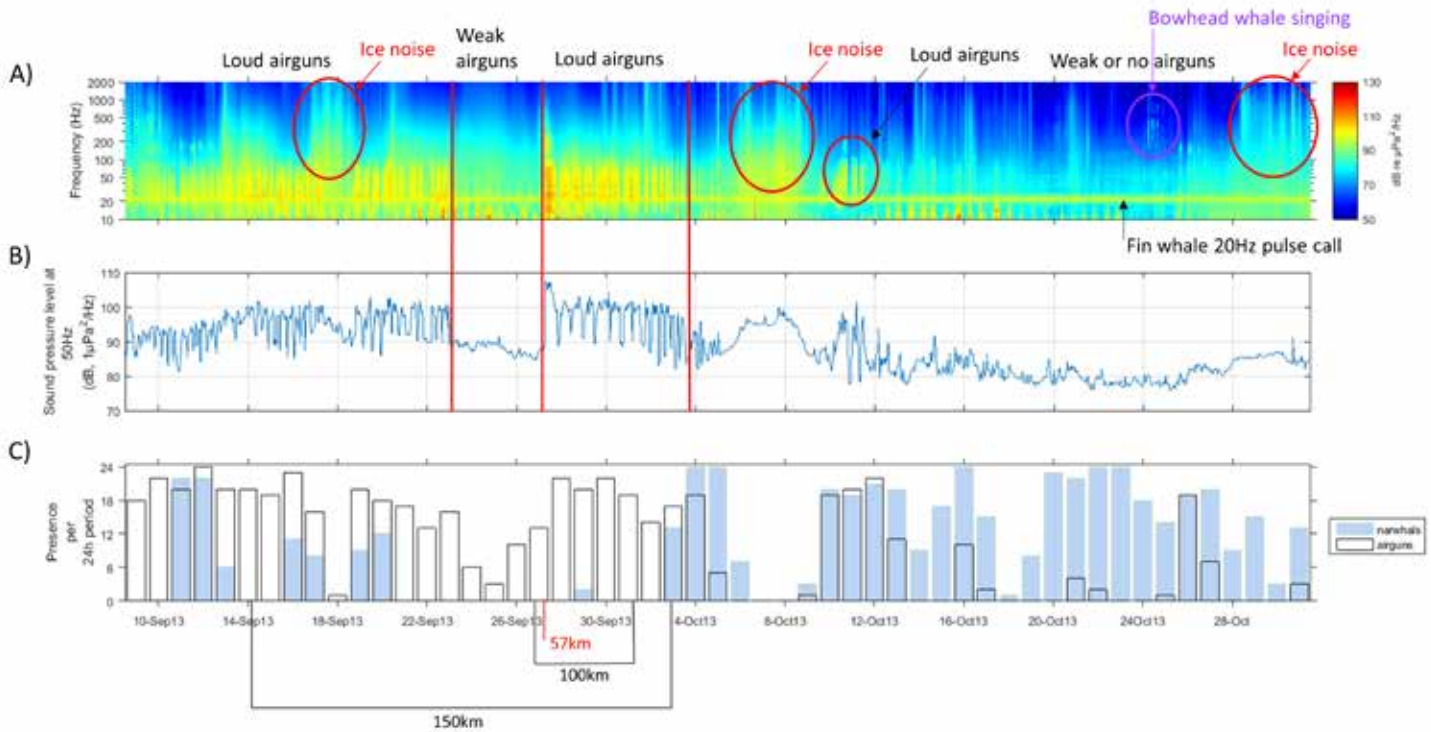


Frequency of (A) bowhead vocalisations, (B) airgun signals, and (C) narwhal vocalisations in Fram Strait (2008-2014), by month. (Asterisks indicate months when no data were collected in some years.)

Ahonen et al. unpublished data

Examples of the data recorded by the AURALS (in this case the Fram Strait AURAL from 9 September to 31 October 2013). Panel A shows loud airgun signals as well as ice noise and bowhead whale and fin whale vocalisations. Panel B shows noises generated by airguns, and panel C illustrates the simultaneous presence of airguns and narwhals. At the bottom of panel C, the distances between survey vessels and the recorder are given.

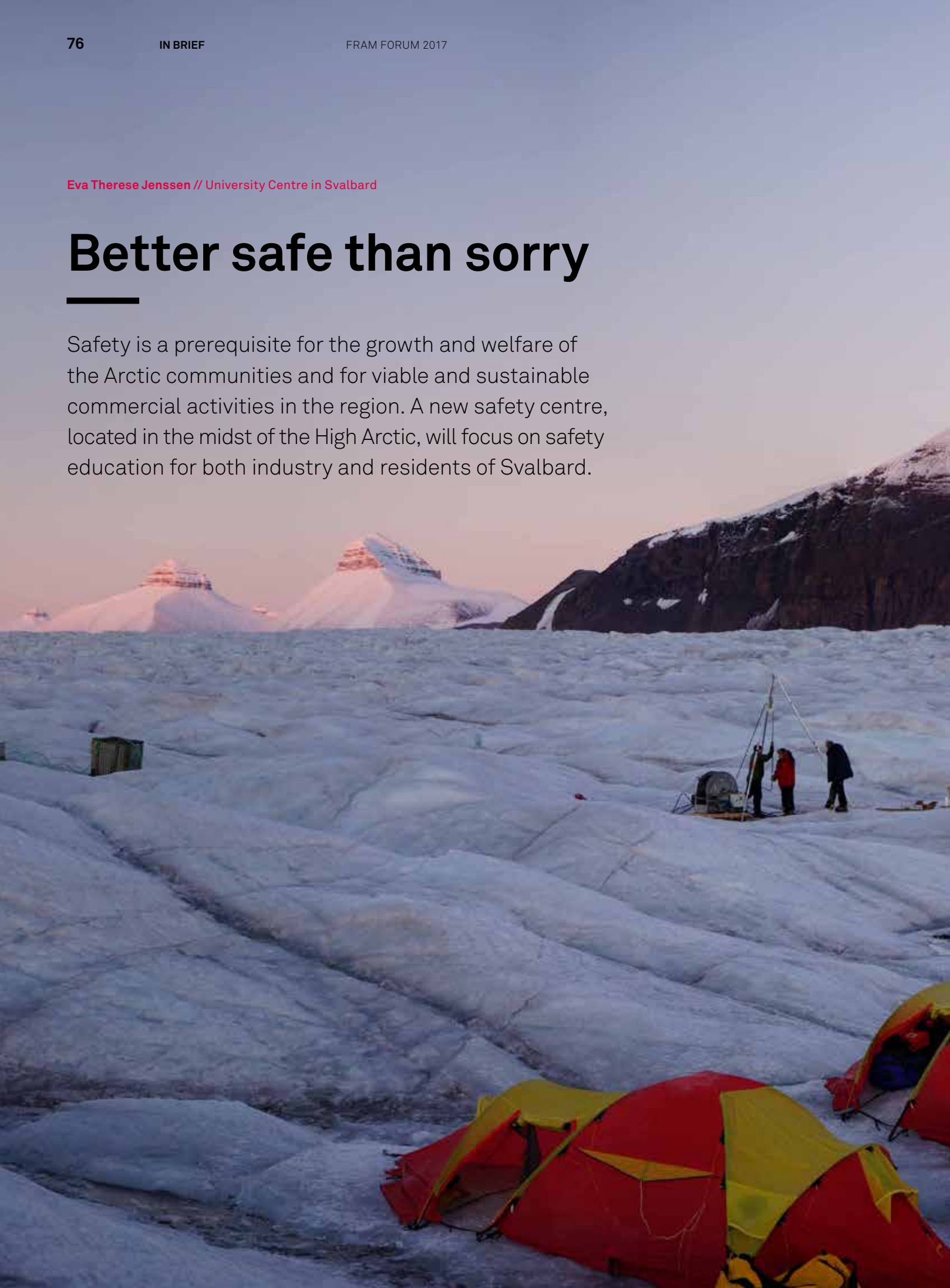
Ahonen et al. unpublished data



Eva Therese Jenssen // University Centre in Svalbard

Better safe than sorry

Safety is a prerequisite for the growth and welfare of the Arctic communities and for viable and sustainable commercial activities in the region. A new safety centre, located in the midst of the High Arctic, will focus on safety education for both industry and residents of Svalbard.



UNIS field camp on Kronebreen in Kongsfjorden, Svalbard.
Photo: Heïdi Sevestre / UNIS

UNIS students digging through an "avalanche" during the winter field safety course.
Photo: Frede Lamo / UNIS

THERE IS A SAYING IN SVALBARD: If you don't know what you're doing in Svalbard, Svalbard will kill you. This rather drastic statement is equally applicable for most of the High Arctic.

The natural environment in the far north is undergoing rapid change. At the same time, the interest in economic development in the region – and in having a national presence there – has never been greater. As a consequence, there is an acute need for increased competence and sharing of experience in how to operate in a safe and environmentally sustainable manner in the High Arctic.

The University Centre in Svalbard (UNIS) has drilled students and staff in safe arctic behaviour since 1993. Each year, several hundred students and staff must complete safety courses before they are permitted to go out on fieldwork in Svalbard. Now this accumulation of highly relevant knowledge will be shared with the world – in the new Arctic Safety Centre (ASC).

In 2015 UNIS, together with a host of partners (see fact box), received NOK 7 million from the Norwegian Ministry of Foreign Affairs to start up the centre. The centre partners will also contribute NOK 7 million, so the total budget is NOK 14 million for the project period from 2016 until 2019.

The purpose is to contribute to making human activity in the High Arctic as safe and sustainable as possible.

A BEAUTIFUL BUT HARSH MISTRESS

Conditions in the Arctic are different than on the mainland and many other places in the world. The greatest challenges are the harsh climate, little or no access to communication lines and – not least – the vast distances.

"Our ambition is that the centre shall share this knowledge through education, tailor-made courses, and guidance for students, industry, and residents of Longyearbyen", explains ASC project manager, Ann-Christin Auestad. "The concept is to utilise existing safety theory and tie it together with best practice routines, and events. All this will lead to better solutions and planning for people working under extreme arctic conditions."

Svalbard is increasingly popular among tourists and scientists alike, also in summertime. But even if ocean temperatures are above freezing, survival suits are a must when landing on Svalbard's shores.
Photo: Steve Coulson / UNIS

BEST PRACTICE + NATURAL SCIENCES

The ASC will also integrate the natural sciences to improve field safety, using observations obtained through SIOS (Svalbard Integrated Observation System). As Auestad puts it: "We are looking at the safety principles in a different context. It's not like we're going to reinvent the wheel, but we want to incorporate best practice routines together with the arctic natural science disciplines."

In concrete terms, the main goal of ASC is to establish a package of Master level courses in Arctic Safety for students specialising in social sciences, natural sciences, and engineering. It will not be a full master programme: the idea is that students already enrolled in master programmes can come to UNIS for a semester or year to specialise in Arctic Safety. These courses will then count towards their degree at their home university.

ARCTIC SAFETY CENTRE

NORWEGIAN PARTNERS:
Norwegian University of Science and Technology
UiT The Arctic University of Norway
University of Stavanger
Norwegian Polar Institute
Governor of Svalbard
Visit Svalbard
Pole Position Logistics
Svalbard Satellite Station (Svalsat)
Longyearbyen Community Council
Lufttransport

INTERNATIONAL PARTNERS:
University of the Arctic
University of Copenhagen
INTERACT
Forum of Arctic Research Operators

Every year, UNIS educates hundreds of students in Arctic safety. As part of the winter field safety course, students must swim through ice-filled water and manage to get back up onto the sea ice again.
Photo: Frede Lamo / UNIS

There is no such educational offer anywhere else: neither in Norway nor abroad, according to Auestad. “That is why we experience such a huge interest for this new centre, both nationally and internationally”.

The education part of the centre is not meant exclusively for students coming to Svalbard, but is also very much intended to include courses for the local populace, thus turning Longyearbyen into a “High Arctic safety awareness community”.

Among the international partners in the project is the International Network for Terrestrial Research and Monitoring in the Arctic, or INTERACT for short. An infrastructure project funded by the EU, INTERACT is a circumarctic network of 77 terrestrial field bases in northern Europe, Russia, USA, Canada, Greenland, Iceland, the Faroe Islands, and Scotland, as well as stations in northern alpine areas. The ASC will develop a generic safety course for the leaders of these INTERACT field bases, and produce a textbook for this specific course.

Another ambition for ASC is to tailor specific safety course modules for the oil and gas industry and the tourist industry.

The planning is already well underway. Already in February 2017 there will be extensive seminars for the local population. In 2018 a pilot course will be offered for Master’s students.

FURTHER READING:

http://www.unis.no/resources/arctic-safety-centre/

Trude Haugseth Moe // UiT The Arctic University of Norway

SOS from the Arctic

What if a ship loaded with toxic chemicals founders in the Arctic during the dark months of the polar night? What will become of the crew? And what about the toxic cargo and the fuel that will soon sink through the icy water? How will they affect slumbering ecosystems deep in the winter-dark seas?

Photo: Karine Nigar Aarskog / UiT The Arctic University of Norway

THESE ARE SOME OF THE MANY QUESTIONS raised by shipping in the Arctic. The short answer is that a shipwreck is bad news. Human lives will probably be lost. Besides, those ecosystems do not sleep through the dark months. In fact, many species thrive in moonlight and under the northern lights - and this means that nature is vulnerable all year round, even during the polar night.

FOUNDERING IN THE ARCTIC

Imagine that it is November; we are in the dark months and it is bitterly cold in the Arctic. The *Oleum*, a freighter from Hamburg, is nearing Novaja Zemlya on her way towards the Kara Sea. Her cargo of chemicals is destined for an oil platform in Siberia. In the middle of the bitterly cold polar night, the winds pick up, the waves grow huge and the *Oleum* rolls and pitches perilously. Suddenly the engine stops. In despair, the captain realises that they are unable to cast anchor because of a thick layer of ice over the anchor winch. The ship drifts helplessly towards land and founders.

MELTED ARCTIC ICE MEANS NEW TRAFFIC

This fictitious scenario formed the starting point for the major cross-disciplinary research project called "A-lex", which addresses the political, legal, environmental, and technological challenges associated with a completely new type of shipping in the Arctic. The background for the project was that over recent years the sea ice in the Arctic has melted so much that the Northeast Passage is open. Nowadays it is possible - for parts of the year - to sail between Asia and Europe via the Arctic.

HIGH RISK OF LOSS OF HUMAN LIFE

One of the researchers' sobering conclusions is that human lives are likely to be lost if ships founder in the Arctic. Search and rescue services are too far away to be of immediate assistance after accidents. The Arctic is far away from infrastructure; the weather is cold and variable, and conditions are physically demanding for humans. For instance, how would thousands of elderly passengers on a cruise ship cope with this kind of situation?

The project has also uncovered a multitude of legal issues concerning international regulation of shipping, liability and compensation for accidents, and safety for both crews on the ships and search and rescue teams.

POLAR NIGHT – LIVELIER THAN IT SEEMS

What about the environment? Many of the factors at work in arctic ecosystems in the winter are unknown, as winter research has (understandably) been sparse. It is only in the past 3-4 years that scientists from UiT have started going on winter expeditions to the Arctic Ocean.

Until recently, the assumption has been that since sunlight is the basis for all biological production on land and in the sea, and since the sun does not shine in the Arctic during the winter, there is no biological activity in the polar night. And indeed, most seabirds and whales migrate south for the winter - but life doesn't stop. "This 'established assumption' has now been challenged and in many ways repudiated", says Lars-Henrik Larsen from Akvaplan-niva.

"Fish eat and reproduce in the dark; there is an abundance of zooplankton and they thrive in moonlight and the northern lights", the scientist asserts.

CHEMICALS IN THE COD SPAWNING GROUNDS

So what about the chemicals that disappeared into the dark depths of the sea when the fictitious ship *Oleum* foundered? The spillage will probably seriously affect the ecosystem. The place where the imaginary *Oleum* sank is in fact the spawning ground for polar cod. The fish are not present when the ship's toxic cargo sinks, but swim in to spawn a couple months later. We know little about how diesel and chemicals might affect the success of the polar cod's spawning.

"We see that even though the resources (the fish) in the sea are not present when an accident occurs, a

Photo: Karine Nigar Aarskog / UiT The Arctic University of Norway

spillage of chemicals or petroleum may harm them at a later time. The resources in the sea are not isolated in time and space, and one must look at both short-term and long-term consequences of an accident", says Lars-Henrik Larsen.

HOPE FOR MORE RESEARCH

Tore Henriksen, leader of the K. G. Jebsen Centre for the Law of the Sea (JCLOS) at the Faculty of Law at UiT, hopes that it will be possible to continue research in this area.

"Cross-disciplinary research collaboration is both challenging and at the same time very useful. One has to communicate so that people outside one's own field understand. But now that we have acquired so much knowledge in the different fields, we would like to continue and we will work to achieve that", Henriksen concludes.

A-lex is a collaboration project between the FRAM Centre, the Faculty of Law and the Faculty of Humanities, Social Sciences and Education, both at UiT The Arctic University of Norway, Marintek, and Akvaplan-niva. Its full name is *A-lex: Regulating arctic shipping: Political, legal, technological and environmental challenges*

The four-year project has been funded by the Norwegian Ministry of Foreign Affairs, the Research Council of Norway, the FRAM Centre and UiT.

FURTHER READING:

https://en.uit.no/prosjekter/prosjekt?p_document_id=363938

Arto Miettinen and Katrine Husum // Norwegian Polar Institute

Paleoceanography reveals ocean conditions millennia back in time

Climate change is real: even most skeptics now acknowledge that. Still, Earth's climate has always changed. Is the current warming trend in any way unusual? Perhaps the answer lies at the bottom of the sea in the form of microfossils, tiny plants and animals that once lived in the ancient oceans.

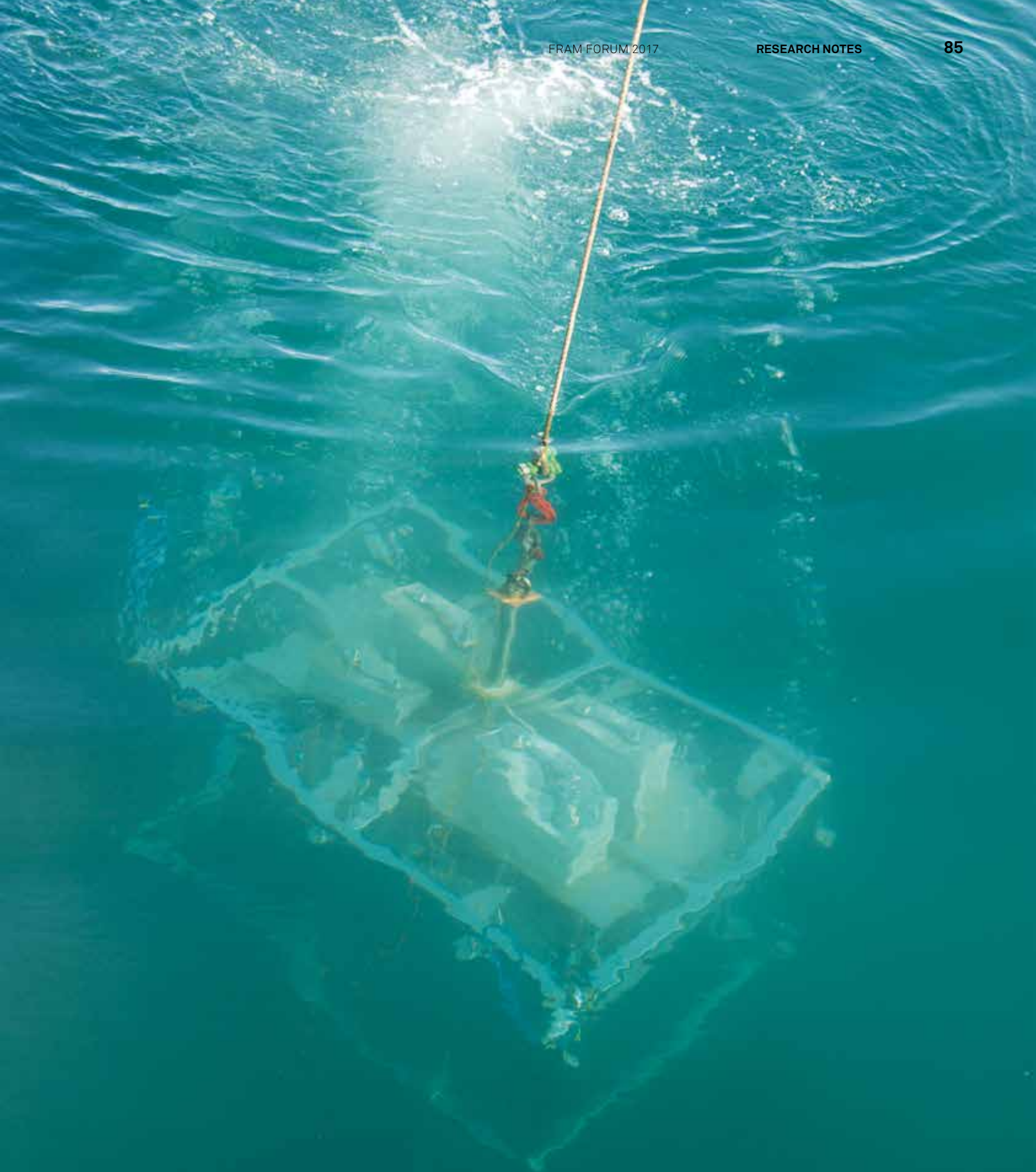
Paleoceanographers reconstruct past oceanic conditions using so-called paleo proxies (e.g. microfossils, such as diatoms and foraminifera). Proxies in marine sediment cores provide "indirect measurements" of oceanic properties in eons past. Direct instrumental measurements of sea ice cover and ocean temperatures have only been done for the past 150 years, whereas marine sediment cores can be utilised to extend the records of ocean conditions hundreds or even thousands of years back in time. Knowledge of past ocean conditions is important, because it defines the baseline of natural climate change and thus allows us to set recently observed changes in the long-term natural climate context. It also helps improve global climate models, enabling more precise climate projections for the future.

DIATOMS: PALEOCEANOGRAPHIC RESEARCH TOOLS

Microscopic diatoms are the most species-rich group of algae. They live in the uppermost surface waters because they are dependent on light for photosynthesis. Sea surface temperature, sea ice conditions, light and nutrient levels, the stability of the surface water layer, and grazing are the most important factors determining the distribution and abundance of diatoms in the ocean surface waters. The species composition of living diatom communities is closely related to modern oceanic conditions, and fossil diatoms are good indicators of past ocean surface conditions (e.g. temperature, sea ice) in the North Atlantic and polar oceans. Methods for diatom-based quantitative reconstructions of sea surface temperature and sea ice concentration have been developed at the Norwegian Polar Institute over the last years. These methods are based on calibration data sets consisting of information on modern diatom assemblages found on the surface of seabed sediment and modern surface temperature and sea ice data from the northern North Atlantic. Statistical transfer function methods then enable us to reconstruct past sea surface temperatures to within about 0.8°C and past sea ice coverage with an accuracy of about ±13%.

HINTS ABOUT ANCIENT OCEAN CONDITIONS

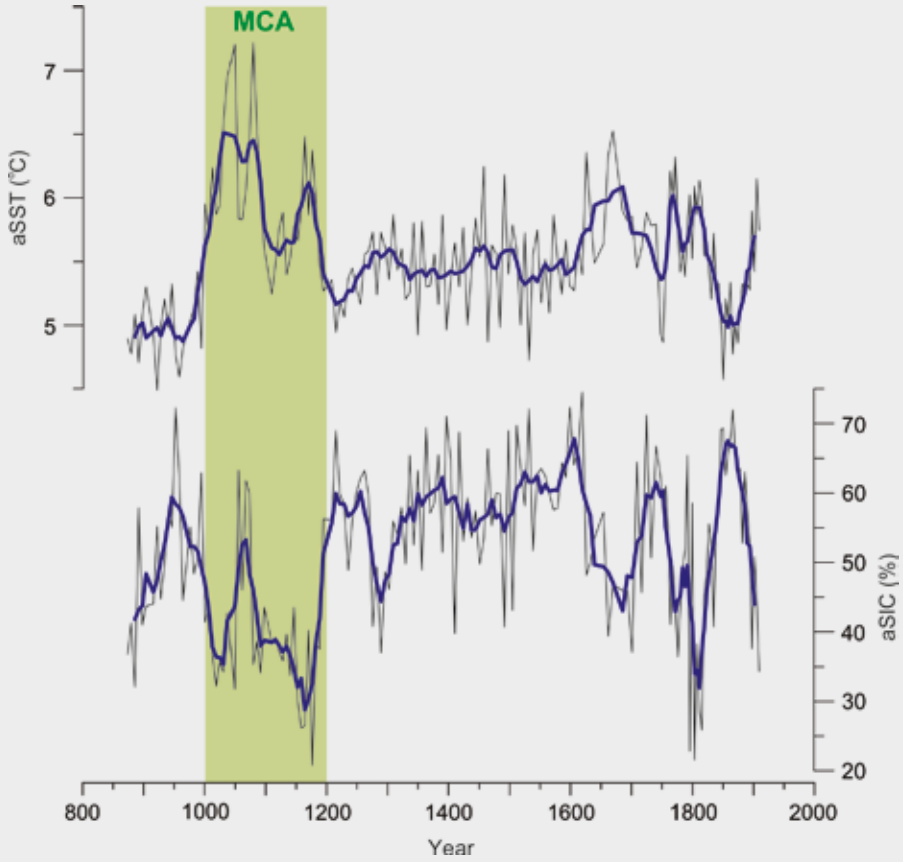
Recent results based on studies of fossil diatoms from the SE Greenland shelf demonstrate that the warmest ocean surface conditions in the area over the last millennium (prior to 1910) occurred between 1000 and



A multicorer going down to collect sediment cores from the seafloor in Kongsfjorden.
Photo: Arto Miettinen, Norwegian Polar Institute

A sediment core including undisturbed surface sediment from the seabed.
Photo: Arto Miettinen / Norwegian Polar Institute

Common subfossil diatoms of the Arctic. *Actinocyclus curvatulus* (upper left), *Rhizosolenia hebetata* f. *hebetata* (upper right), and the sea ice species *Fragilariopsis oceanica* (lower left), *Thalassiosira gravida* (lower right).
Photos: Arto Miettinen / Norwegian Polar Institute



Reconstructions of August sea surface temperature (aSST) and April sea-ice concentration (aSIC) from the SE Greenland shelf (modified from Miettinen et al. 2015).

1200 AD, a time period called the Medieval Climate Anomaly (MCA). The results also show that the changes were abrupt, i.e. on a decadal to multidecadal time scale. Comparison with regional air temperatures, reconstructed from Greenland ice cores, indicates that ocean surface warming lagged about 50 years after atmospheric warming. This lag may be due to an initial cooling effect of increased freshwater discharge from the Greenland ice sheet or intensified sea ice export from the Arctic in response to atmospheric warming at the beginning of the MCA. The data also show that the cool phase associated with the Little Ice Age (1200-1890 AD), ended with a rapid warming of the sea surface and diminished sea ice concentration in the early twentieth century.

The oceanic response both to the shorter-term MCA warming and longer-term solar forcing indicates that the SE Greenland shelf is a climatologically sensitive area where even extremely rapid oceanic changes are possible. The regional influence of the Greenland ice sheet can be prominent in the conditions of warming climate as seen during the early MCA. Oceanic changes can have an impact on global climate through their potential influence on the ocean circulation system in the Atlantic. This highlights the importance of the Greenland ice sheet and the neighbouring ocean under the present warming conditions.

FURTHER READING:

Miettinen A, Divine D, Husum K, Koç N, Jennings A (2015) Exceptional ocean surface conditions on the SE Greenland shelf during the Medieval Climate Anomaly. Paleoceanography 30, 1657-1674, doi:10.1002/2015PA002849

Harald Steen, Jack Kohler, Philipp Assmy, Haakon Hop, Pedro Duarte, Anette Wold and Arild Sundfjord // Norwegian Polar Institute

Tidewater glacier fronts: Arctic oases in retreat

Tidewater glaciers are iconic symbols of the Arctic, towering majestically above the water and losing ice spectacularly by calving. Beneath the surface they maintain a vital local oasis where food is plentiful. But Svalbard's tidewater glaciers are retreating, and the future of these Arctic oases is uncertain.

Tidewater glaciers terminate in the sea, rather than on land, occurring as impressive vertical walls of ice. At the front, blocks of ice break off and plummet into the sea, a process known as calving. The ice cliff below the surface and the calved icebergs cool the ocean, creating a local environment suitable for arctic species that thrive in cold water.

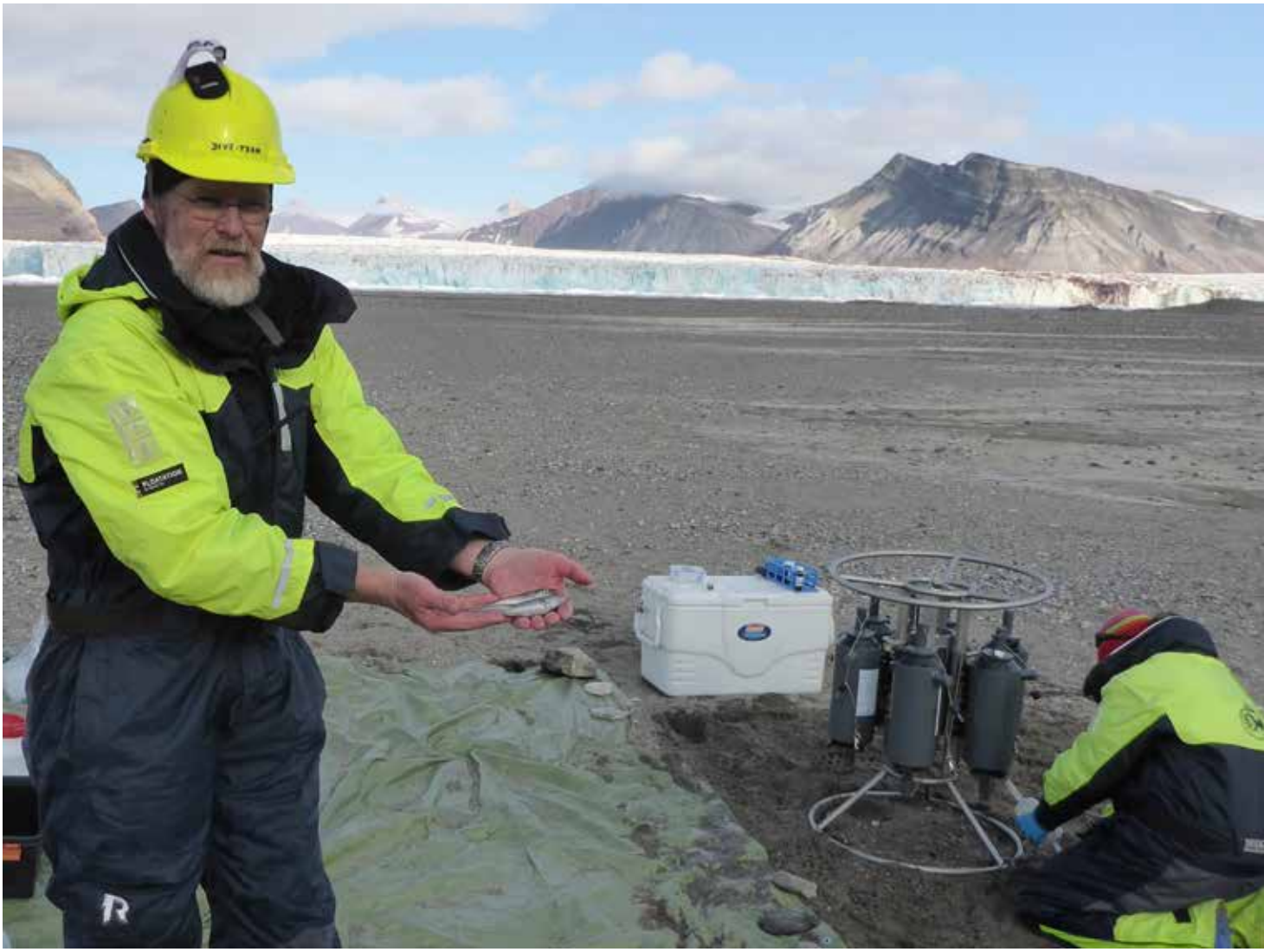
A WELL-FILLED LARDER

At the glacier surface, meltwater and summer rain find their way through cracks and crevasses to the glacier bed, flowing toward the glacier front, where the water is released at depth. This water is lighter than the seawater, and thus rises, forming a *plume*. The plume can rise very rapidly, bringing zooplankton and polar cod to the surface. Furthermore, zooplankton can experience osmotic shock in the relatively fresh water, becoming stunned, or even dying. Seabirds can then easily pick them near the surface. Marine mammals, such as ringed seals, white whales, and polar bears can all be found at or close to tidewater glacier fronts, attracted to this primary food source.

Kongsfjorden (at 79°N) used to be ice-covered during winter, but since 2006, increasing sea and air temperatures have resulted in years with little or no sea ice. As the fjord gets warmer, species dominance shifts from arctic specialists to boreal species. However, the cold and less saline environment close to the glacier front may still serve as a refuge for arctic species. We want to understand how tidewater glaciers impact fjord circulation and hydrography, and ultimately how their effects shape the ecosystem.

COLLECTING SAMPLES

The staple food for polar cod is zooplankton, which in turn depend on phytoplankton. However, the glacier water carries a load of silt that shades out the sunlight necessary for phytoplankton production. This effect extends some kilometres away from the glacier front. Zooplankton are likely brought in from the fjord basin by deep currents and then upwelled to the surface in the plume. To test this hypothesis, we sought to take water samples close to the glacier front.



Standing in the makeshift laboratory at the work site, Haakon Hop holds some of the freshly caught polar cod.
Photo: Harald Steen / Norwegian Polar Institute

In the project *Glaciers as Arctic Refugia* (GLAERE), scientists from the Norwegian Polar Institute worked together with colleagues from Poland and Norway, to understand the importance of tidewater glaciers on fjord hydrography and ecosystems. GLAERE has been extended through the projects *Tidewater Glacier Retreat Impact on Fjord circulation and ecosystems* (TIGRIF) and *Tidewater*-ICE (TW-ICE).

However, working in front of the glacier is dangerous. Falling ice crushes anything in its path, and creates waves that toss floating pieces of ice around. The area is unsuitable for small vessels; even large boats need to keep a safe distance.

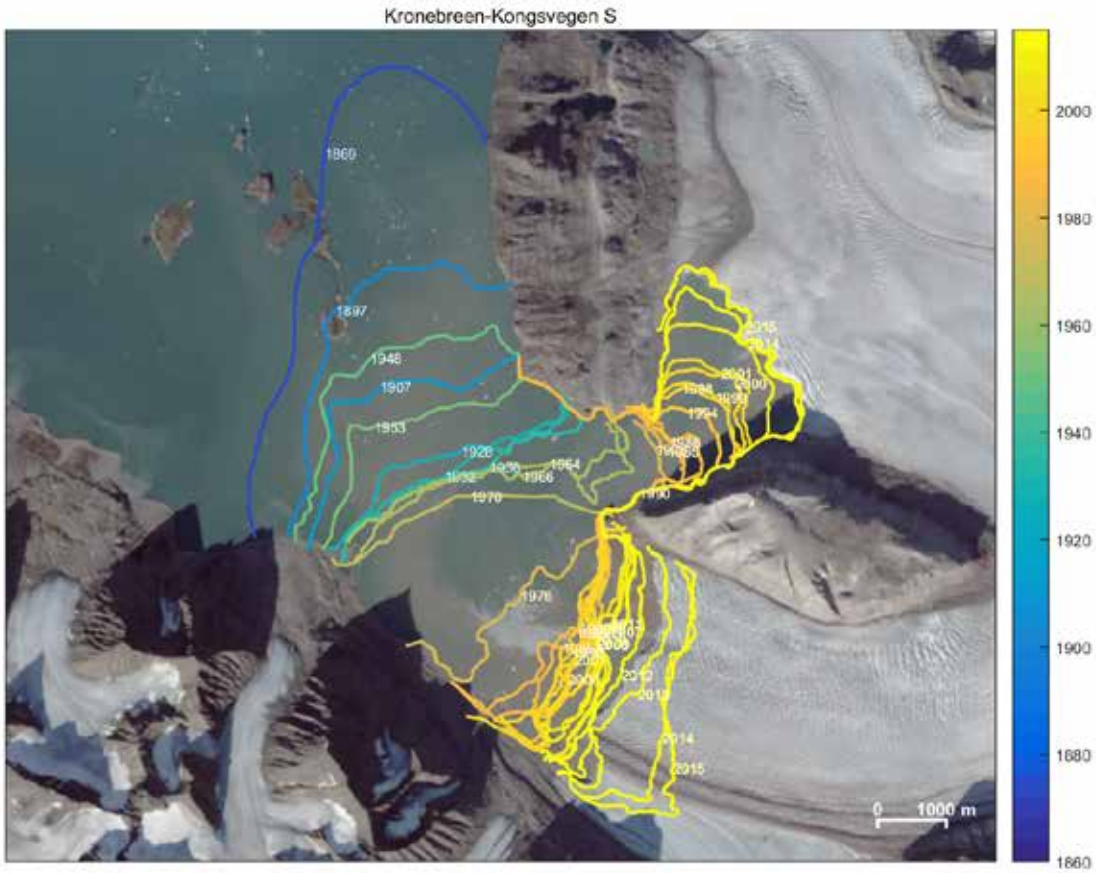
UNEXPECTEDLY SALTY WATER

During the summer of 2016, we used a helicopter and sampled water and plankton right in front of Kronebreen. We found that the water was not as fresh as expected, and that most of the zooplankton we captured in our nets were alive. This supports our understanding that they are forced to the surface by currents, and that they do not die because of osmotic shock. Perhaps the most striking finding was that we also caught polar cod in the plankton net, indicating that there must have been dense schools of fish in front of the glacier.

In Svalbard, the tidewater glaciers are retreating, and the arctic oases in front of the glaciers are in danger of disappearing. It is difficult to predict how long it will take for the glaciers in Kongsfjorden to retreat onto land; this will depend on future climate and on the subglacial topography. However, with no tidewater glaciers, the fjord ecosystem is in danger of losing its characteristic arctic fauna.

Top: Helicopter ready for takeoff with the bottle-rosette to take water samples.
Bottom: Instruments were attached to a weighted 110-metre line suspended below the helicopter.
Photos: Harald Steen / Norwegian Polar Institute

Copepods, amphipods, arrow worms, and krill dominated the zooplankton caught near the glacier front. Most of them were alive, as indicated by neutral red staining.
Photo: Anette Wold / Norwegian Polar Institute



The tidewater glacier Kronebreen lies innermost in Kongsfjorden. Lines and years indicate front positions over time. *Diagram: Jack Kohler / Norwegian Polar Institute*

Arild Sundfjord and Jack Kohler // Norwegian Polar Institute
Jofrid Skarđhamar and Jon Albretsen // Institute of Marine Research

New modelling tools for Kongsfjorden, Svalbard

Considering its remote location, Kongsfjorden is a well-studied system. For years, scientists have meticulously collected data on its physical, chemical, and biological properties, essentially providing snapshots of the fjord. Computer models enable us to simulate fjord dynamics between and beyond field campaigns.

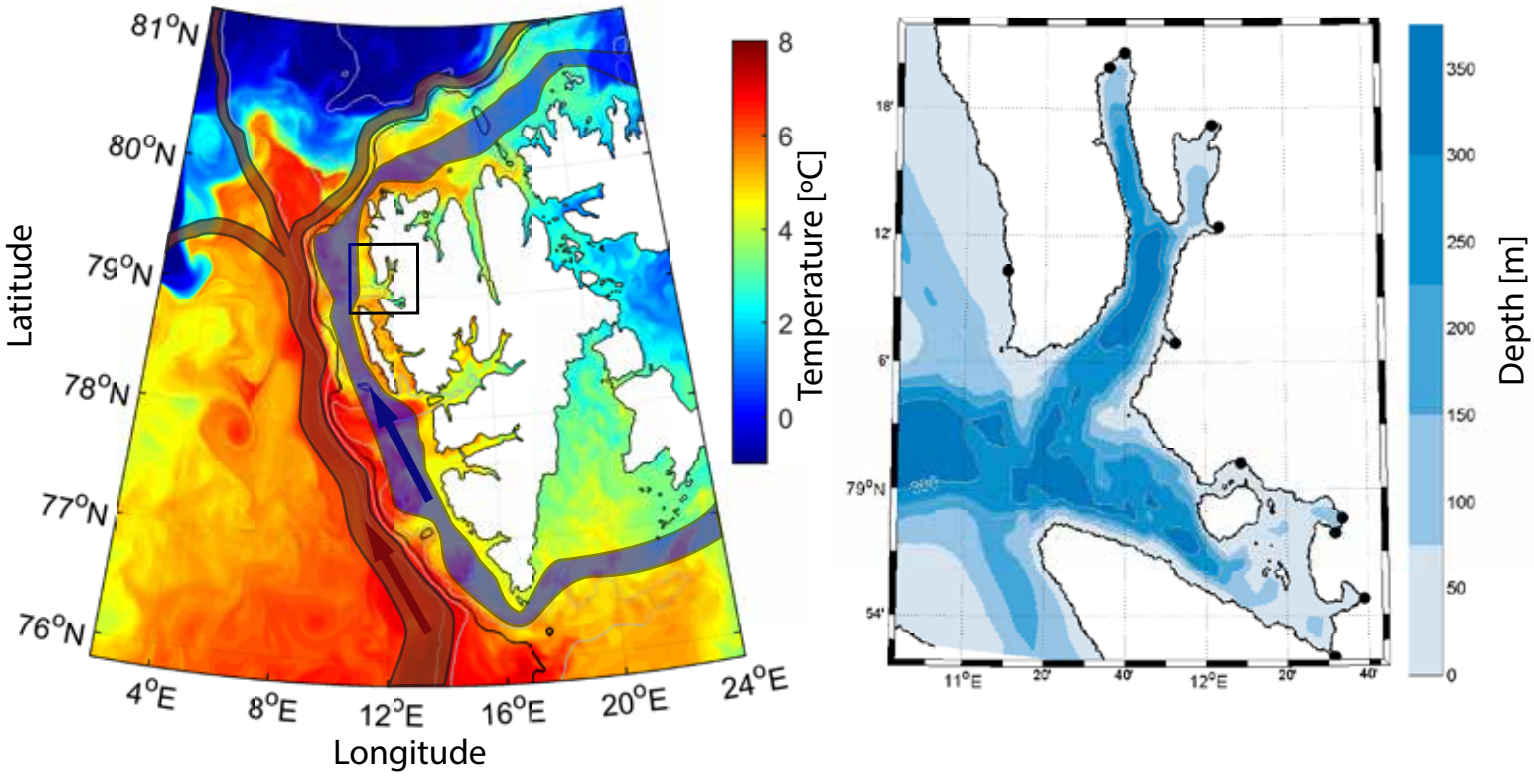
For more than two decades there have been annual cruises in Kongsfjorden to collect hydrographic and biological data. Moorings at strategic locations have provided valuable data on seasonality in the outer part of the fjord. Many research groups have studied various aspects of the fjord's marine life and biogeochemistry. All these data - valuable in themselves - can be leveraged to provide even greater understanding, through use of computer models. Numerical circulation models can complement and integrate findings from short-term measurement campaigns and time series from separate locations, and help answer cross-discipline questions that cannot be properly addressed through field data alone.

CONSTRUCTING AND REFINING OUR MODELS

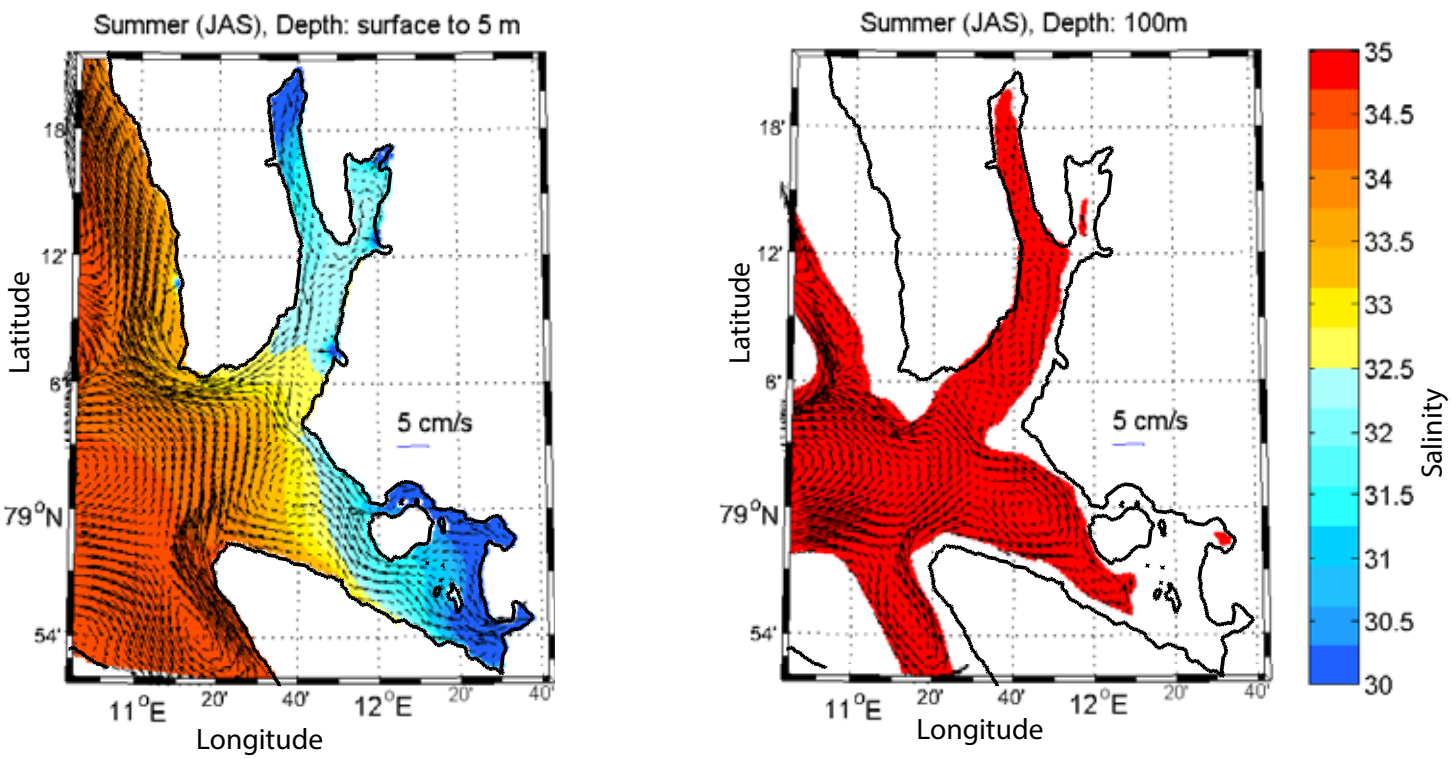
We have established a new model for Kongsfjorden. Building on existing tools, we have assembled new data on fjord bathymetry, glacial runoff and wind to produce multi-year simulations of conditions in the fjord and nearby shelf area. The results have been compared with existing measurements of salinity, temperature, currents and sea ice cover, and the new tools have been found suitable for further use.

Ongoing development will improve the model's accuracy, particularly near the glacier fronts, and the model will be used for budget calculations for ocean acidification, simulations of lower trophic level ecosystems, and predictions of future circulation for scenarios when glaciers may have retreated further, thus changing meltwater runoff and circulation in the fjord.

Fram Centre partners (Norwegian Polar Institute, Institute of Marine Research, University Centre in Svalbard) have established a numerical ocean circulation model setup for Svalbard, based on the Regional Ocean Modeling System - (ROMS) a powerful modelling framework used by scientists all around the world. Kongsfjorden and the adjacent shelf have been set up on a high-resolution horizontal grid with cells of 160 × 160 metres and 35 vertical layers. The ROMS code allows for simulation of temperature, salinity, currents and sea ice cover. The model is forced with wind and other atmospheric forcing. At the off-shore boundaries, the model is fed data from a regional model with 800 m resolution, and tides from a tidal prediction model. We have also assembled a new data set on glacial runoff, based on measurements of glacier and land topography, glacier mass balance, and meteorological forcing. Taken together, this is the most detailed model of the area yet, and forced by the best available data sets.



Map showing part of the S800 model domain (left panel) with surface temperature for an arbitrary date in September 2009 (colour scale), and the area covered by the 160 m Kongsfjorden model (black box). The northward flowing West Spitsbergen Current and the fresher coastal current are illustrated by red and blue flow fields, respectively, with embedded arrows indicating their flow direction. The right panel shows the domain of the 160 m model, with bathymetry (blue colour scale) and glacier runoff positions (black circles).



Modelled mean parameters at the surface (left panel) and at intermediate depth (100 m, right) for July-September 2005-2009 circulation is shown with arrows, and salinity in colours.

The new model for Kongsfjorden builds on regional-scale modelling done in an Arctic Ocean flagship project (ModOIE), where the Fram Strait was simulated with 800 m horizontal resolution. The first phase of the work in Kongsfjorden was supported by the Fjord and Coast flagship (KongHiro project) and the present and planned work is funded by the Research Council of Norway (TIGRIF project).

TESTING MODELS BY COMPARING WITH REALITY

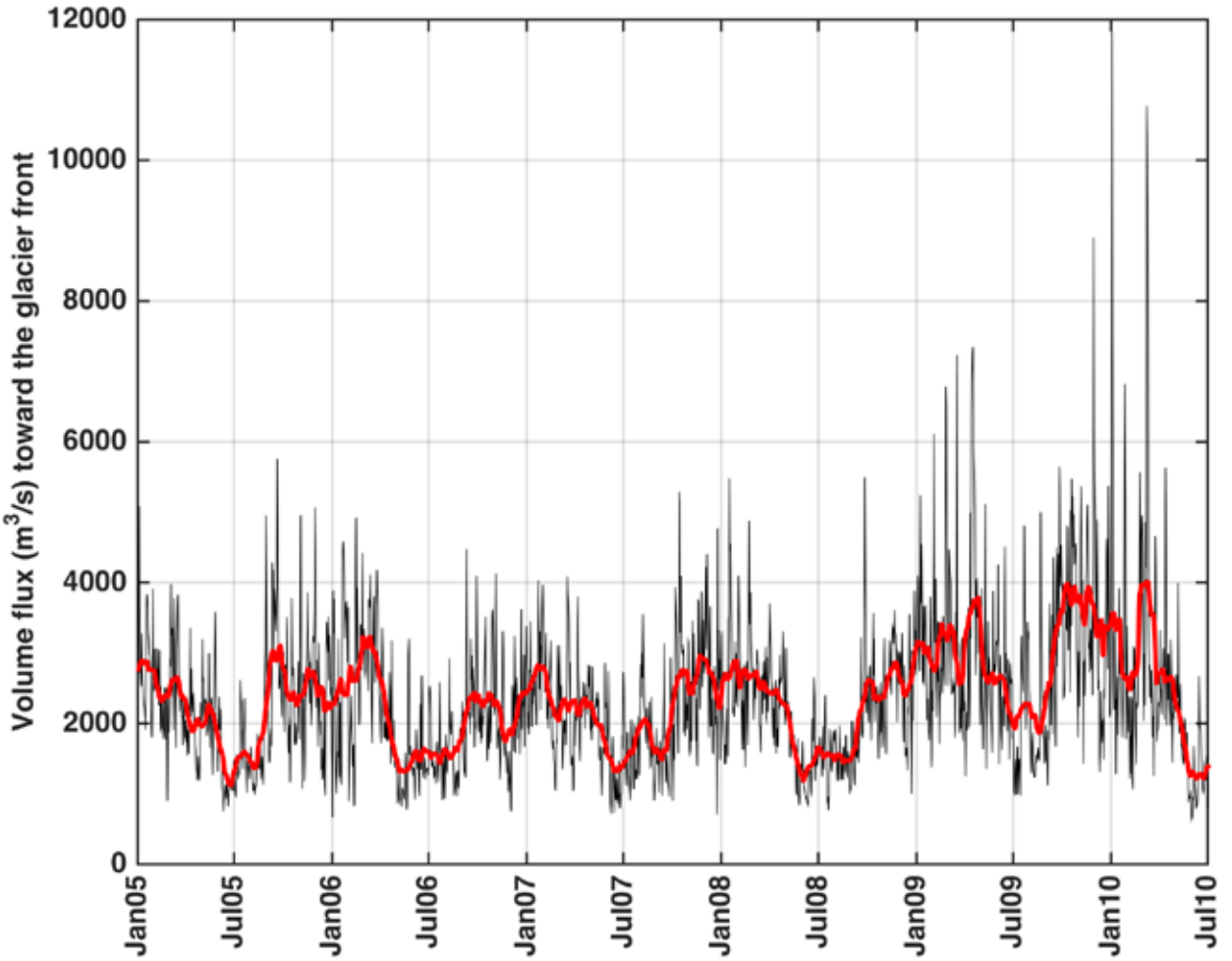
We have assessed the quality of the simulations by comparing with available observational data from moorings, cruises and sea ice cover observations. The model reproduces seasonality in hydrography well, and the chief mechanisms of exchange between the main fjord and the shelf outside appear to be properly represented. Individual episodes of inflow are not always simulated at the same time as in reality, and the resulting hydrography (freshwater content, stratification, minimum and maximum values for temperature and salinity) can therefore deviate from observations. Nevertheless, we found that the model reproduces the overall picture well, and can be used, for example, to calculate the bulk flux of heat and other tracers carried with the water masses into and out of the fjord.

The analysis shows that there is significant circulation all the way into the interior fjord and towards the glacier fronts. This is seen not only in summer - when glacier meltwater drives surface outflow and water flows in at depth to compensate - but all year round. Given that the ocean water is warmer in summer, the potential for ocean-driven glacier front melting is substantially larger in summer than in winter. But the freezing point of (salty) seawater is lower than that of freshwater, and the ocean heat and salinity carried into the fjord in winter will therefore contribute to delaying the establishment of an ice cover and can, periodically, drive melting of any sea ice that forms, even in periods when the seawater temperature is not high enough to lead to melt at the glacier fronts.

One of the main shortcomings of the present model system is that glacier runoff enters the domain as deep "rivers" and not through sub-surface outlet tunnels at the base of the glacier fronts. In reality, as melting starts in late spring, the meltwater enters at the surface, through cracks and crevasses. But as the season progresses, a complex system of internal tunnels forms in the glacier; later in the melting season most of the freshwater comes out tens of metres below the surface at a very limited number of locations at each glacier front. Since freshwater has much lower density than seawater, the meltwater rises rapidly in "plumes", and mixes with ambient water. This introduces different sub-surface dynamics and will set up compensating inflows at different depths throughout the melting season. Some of the discrepancies that were identified when we compared the model results with observations likely stem from this simplification of the model.

ADDRESSING THE MODEL'S WEAKNESSES

We are currently setting up a realistic stand-alone plume model and the plan is to use results from this to introduce a new parameterisation of meltwater runoff in the ROMS framework. Hopefully, this can be used to better assess the impact of glacier runoff in the fjord and along the outer coast, and also be applied in other fjords or coastal areas with tidewater glaciers. We are also setting up the model for a future scenario, building on new radar measurements of sub-glacier topography, to simulate the fjord circulation and sea ice cover in a possible future Kongsfjorden with longer fjord arms and where meltwater enters the fjord only as



rivers flowing down from glaciers that have retreated fully onto land. A lower trophic level ecosystem model will be established, to assess nutrient dynamics and local versus imported productivity in the fjord.

Calculated volume flux toward front of Kronebreen/Kongsvegen, for 2005-2010. Daily values in black and running mean in red. The model can be used to calculate volume fluxes, and thus fluxes of heat, carbon, salinity and other properties associated with water flux. This is extremely difficult to do through observations.

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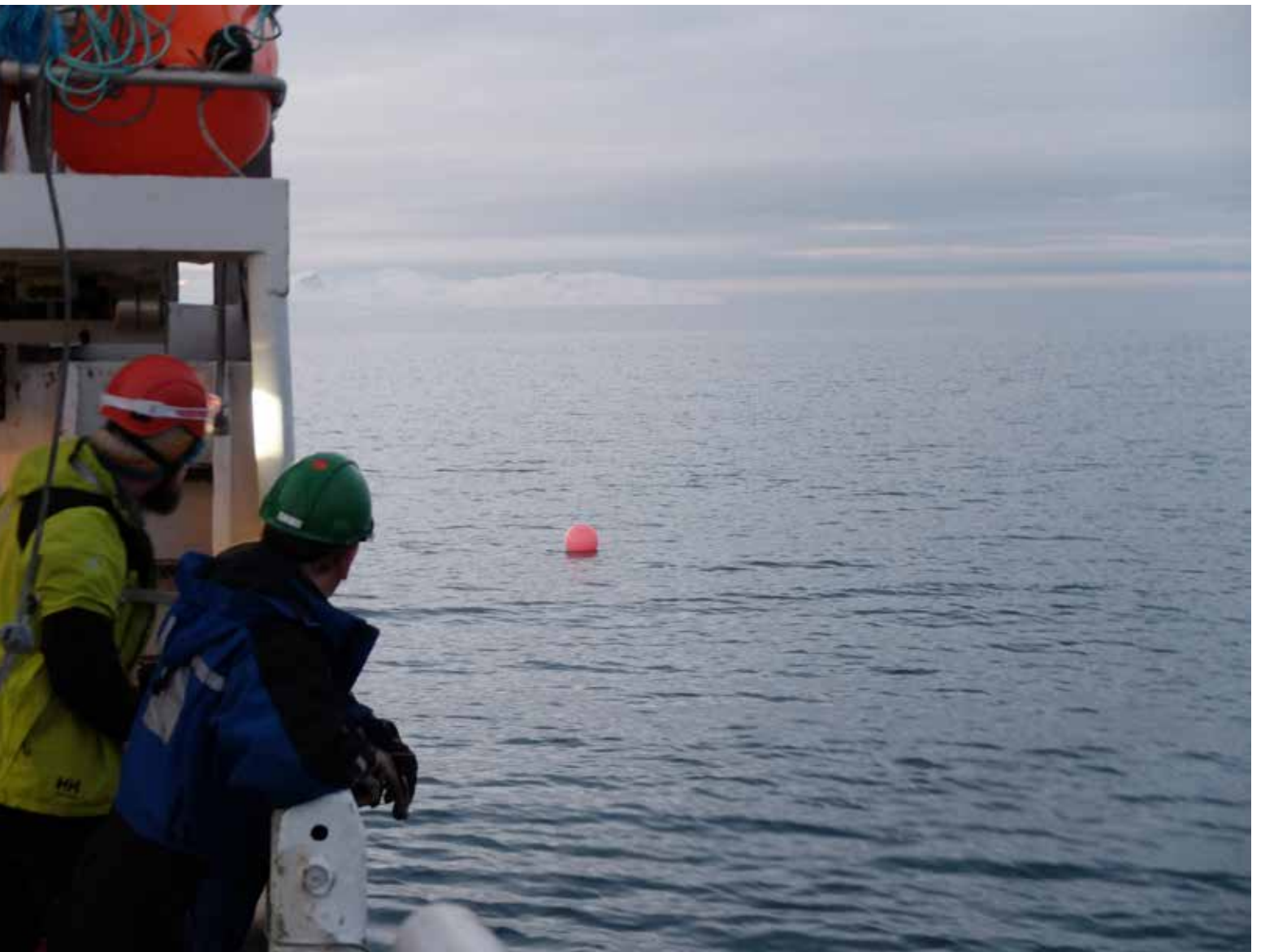
Eva Therese Jenssen // University Centre in Svalbard

Weather station IN the sea

A new underwater measurement station is now deployed in Isfjorden outside Longyearbyen. From now on everyone can monitor the temperature, currents, tides, and biological activity via the internet.

The red buoy indicates the location of the weather station.
Photo: Ragnheid Skogseth / UNIS



For the past ten years, the sea temperatures around Svalbard and in the Barents Sea have increased, resulting in a delayed and much more unstable sea ice season. This has proven to be a growing challenge for a range of human interests, commercial and otherwise, such as tourism companies, logistical operators, and for education and research linked to sea ice.

The reduction in sea ice cover is mainly due to the proximity to the Atlantic heat source in the West Spitsbergen Current, which has increased in the same period. Of all the fjords on the west coast of Spitsbergen, Isfjorden has the strongest link to the heat source through the distinct *Isfjordrenna* across the shelf west of Spitsbergen.

UNCERTAIN CONDITIONS

The warm Atlantic water has been dominant at this site since 2006. Several times over the last ten winters it has flooded the shelf and flowed directly into the fjords on the west coast of Spitsbergen. The sea ice cover, which previously was thick in some fjords and in the side-fjords Billefjorden and Dicksonfjorden, has in recent years been either absent or relatively thin compared to a "normal" year.

Under such episodes of inflow of warm and saline Atlantic water, there is a huge possibility that the warm water can be guided into the fjord ice, which then could melt from below. Weakening of the ice is not directly visible from above: the surface of the sea ice and snow cover can appear normal, so snowmobiling on the fjord ice in recent years has been fraught with risk due to lack of real time information about the dangers lurking beneath the ice.

UNDERWATER WEATHER STATION

The University Centre in Svalbard (UNIS) has now deployed an ocean observatory in Isfjorden outside Longyearbyen to monitor ocean currents and the inflow of warm and saline water into Isfjorden. In addition, a website presents real-time values and historical time series from this "weather station in the sea".

UNIS has received funding from the Svalbard Environmental Fund, and instruments and technical support from Aanderaa Data Instruments AS in Bergen, to realise this new ocean observatory.

The main objective of the project is to develop a tool that facilitates dissemination of information on environmental conditions in Isfjorden, improves prediction of the chances for sea ice formation, and helps assess the risk of travelling on sea ice when sea ice exists. The physical and biological data from this weather station will also provide valuable information about the state of the ecosystem, including the likelihood for harvestable fish stocks to be present in Isfjorden.

"This project will ensure that we have updated information of the climate change impact on the natural environment", says project leader Ragnheid Skogseth, a physical oceanographer at UNIS.

"By looking at the temperature development through late autumn it will also be possible to provide better assessment about the fate of sea ice formation for the next winter", she says.

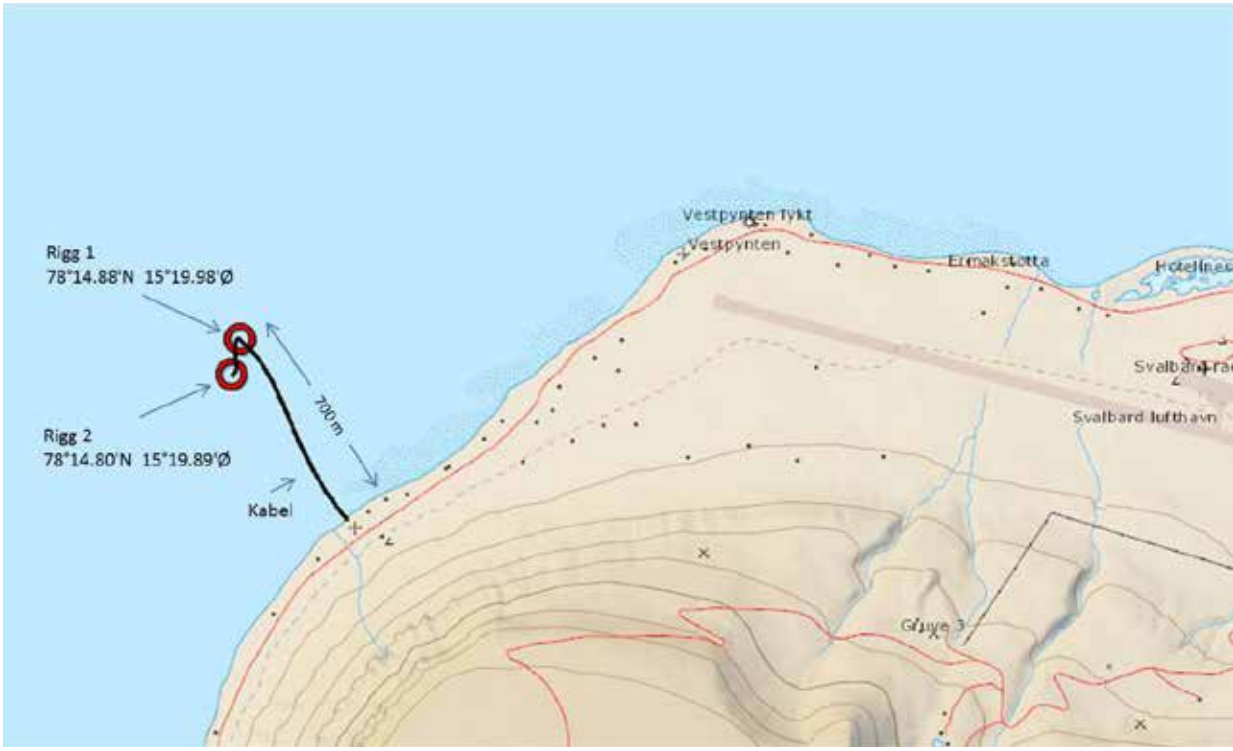
USEFUL FOR EVERYONE – NOT JUST SCIENTISTS

The website and data from the ocean observatory are freely available for the many collaborative projects that UNIS has with kindergartens, schools and institutions of higher education and research.

One part of the project is to launch a comprehensive website with information on current, temperature, and salinity observations at several depths, an ice index that will indicate presence of sea ice at the surface, and a pressure gauge for tidal variations. In addition, primary productivity in the ocean is measured by a fluorometer at 20 m depth. These readings in combination with the light and oxygen measurements will give us valuable information on the biological status of the fjord.

The ocean observatory is located so that it can notify us about the influx of warm and saline Atlantic water all year round and will therefore be of assistance in risk

The weather station was deployed outside Bjørndalen by UNIS in autumn 2016.
Photo: Ragnheid Skogseth / UNIS



The location of the weather station outside Bjørndalen, Svalbard.
Map graphics: Norwegian Polar Institute and UNIS

assessment for traffic on the sea ice in the winter. It will also let us know when we should go fishing. This is because the attractive fish species (cod, haddock, salmon, and mackerel) follow the inflow of Atlantic water.

UNIS and Murmansk Marine Biological Institute (MMBI) have taken the initiative to establish a high-Arctic seasonal time series in Isfjorden: Isfjorden Marine Observatory System (IMOS). This joint Norwegian-Russian project will provide a long-awaited tool to help scientists and others target their sampling of other important physical and biological parameters that can only be retrieved by boat.

IMPORTANT FOR FUTURE SHIPPING PLANS

Isfjorden is the largest fjord along the west coast of Spitsbergen and has always been a strategic inlet for Svalbard's settlements. Given the large year-to-year variations in the amount of sea ice around Spitsbergen, and even permanent sea ice cover in some places, the bay was an obvious natural fairway.

The ongoing climate change will reduce sea ice cover and affect sea traffic patterns in the north. Longyearbyen community council and local businesses are working to make the port of Longyearbyen a hub in future shipping across the Arctic Ocean. The planned ocean observatories will be placed along the fairway to Longyearbyen and will provide valuable information about tides and currents to the growing number of ships in Isfjorden.

By looking at temperature and salinity observations and how they develop through late fall, it will also be possible to help local tourist operators with information about the likelihood of sea ice forming the next winter. This will allow them to plan safer and more attractive excursions in the upcoming season. Data from the ocean observatory will be important for long-term data series on plankton in Isfjorden, a project in which UNIS and Russian scientists in Barentsburg collaborate. Data can also be used for research-based tourism. For example, one might offer boat excursions where tourists hear lectures, then participate actively in temperature and salinity measurements, or plankton sampling.

Graphs showing current (speed and direction), temperature, salinity, oxygen content, chlorophyll content, light conditions, and tides in Isfjorden over the past few days can be viewed here: http://aanderaaeng1.cloudapp.net/AADI_DisplayProgram/setups/hc_unis/default.aspx

Per Inge Myhre // Norwegian Polar Institute

Offline digital geological map of Svalbard

Geological information is now available “to go”, for geoscientists, for researchers, for anyone curious about Svalbard’s natural environment: Last year the Norwegian Polar Institute published a digital geological map of Svalbard for mobile devices.

Geological maps are made using scientific methods and form the state of knowledge and basis for geological research in a region. Information about geological features, including type, age, structure of rocks and sediment, is presented with different colours, lines and text descriptions. Digital versions of these data allow geological maps without the constraints imposed by paper sheets with fixed scale.

The new offline digital geological map from the Norwegian Polar Institute contains a wealth of information – and it all fits in a pocket. Decades of mapping, often with long and logistically demanding expeditions, have so far resulted in around 35 map sheets published by the Norwegian Polar Institute geological mapping programme. A map covering all of Svalbard at high resolution became available as part of the Geoscience Atlas of Svalbard in 2015, and this is used as the geology layer in the offline mobile map.

Geological mapping is iterative in nature: new data, observations, and interpretations make it necessary to change existing maps. In other words, a geological map of an area is never finished. Instead there is a never-ending challenge to manage the information and make it available to the scientific community. The offline mobile map is an effort to meet this challenge.

In a glaciated region like Svalbard, the landscape constantly changes as glaciers melt. New outcrops emerge from ice and moraine fields. To mark these areas, we have used the most recent glacier outlines available. Along with up-to-date topographic data (also provided by the Norwegian Polar Institute), this new tool makes it easier to plan and conduct field work anywhere in Svalbard.

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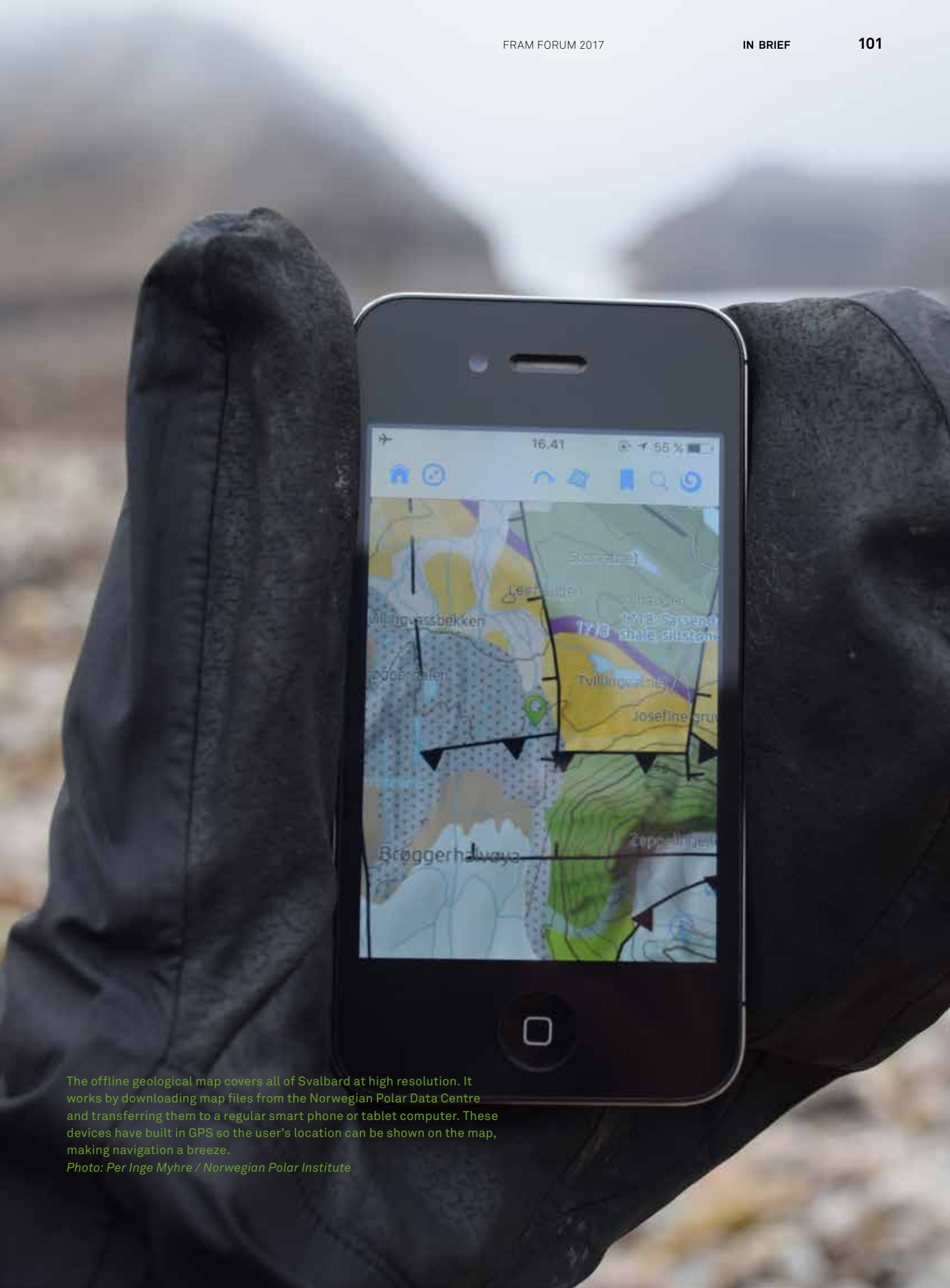


The offline geological map covers all of Svalbard at high resolution. It works by downloading map files from the Norwegian Polar Data Centre and transferring them to a regular smart phone or tablet computer. These devices have built in GPS so the user's location can be shown on the map, making navigation a breeze.
Photo: Per Inge Myhre / Norwegian Polar Institute

Kenichi Matsuoka // Norwegian Polar Institute

Antarctic ice rises: small in size but big on impact

Ice discharge from the Antarctic Ice Sheet directly impacts global sea level, making ice sheet dynamics a central topic in antarctic research. Glaciologists are studying a poorly understood but potentially important phenomenon that looks like a little hill of ice. They call these hills "ice rises".

WHEN ANTARCTIC ICE IS DISCHARGED from land to the ocean, the ice does not melt immediately but becomes a floating ice shelf. Because the ice shelf is afloat, it contributes toward raising the sea level even before it breaks free of its parent ice sheet. So, does that mean the collapse of the ice shelves makes no difference for sea level rise?

The answer is a definite "No!" Although the shelf ice is already afloat, it still holds back the upstream grounded ice and thus its collapse could open the way for more ice discharge. Indeed, soon after the collapse of the Larsen B Ice Shelf on the Antarctic Peninsula, in February 2002, upstream glaciers speeded up, lost ice, and thinned. Its neighbour to the south, the Larsen C Ice Shelf, is now poised to calve a giant iceberg, and the scientific community is paying close attention to this ice shelf to track its impact on the stability of the ice shelf and upstream ice sheet.

LOCAL FEATURES: RISES AND RUMPLES

Antarctic ice shelves have local features that form when the ice is "stuck" on elevated seabed. These grounded features, called ice rises and rumples, give significant buttressing to the ice shelf. Ice rises typically ascend to several hundred metres above the surrounding ice shelf. Each ice rise has its own local ice flow from the summit (see diagram), and ice flowing from the shelf is diverted around it. On the other hand, shelf ice flows over ice rumples, which typically rise only a few tens of metres above the ice shelf.

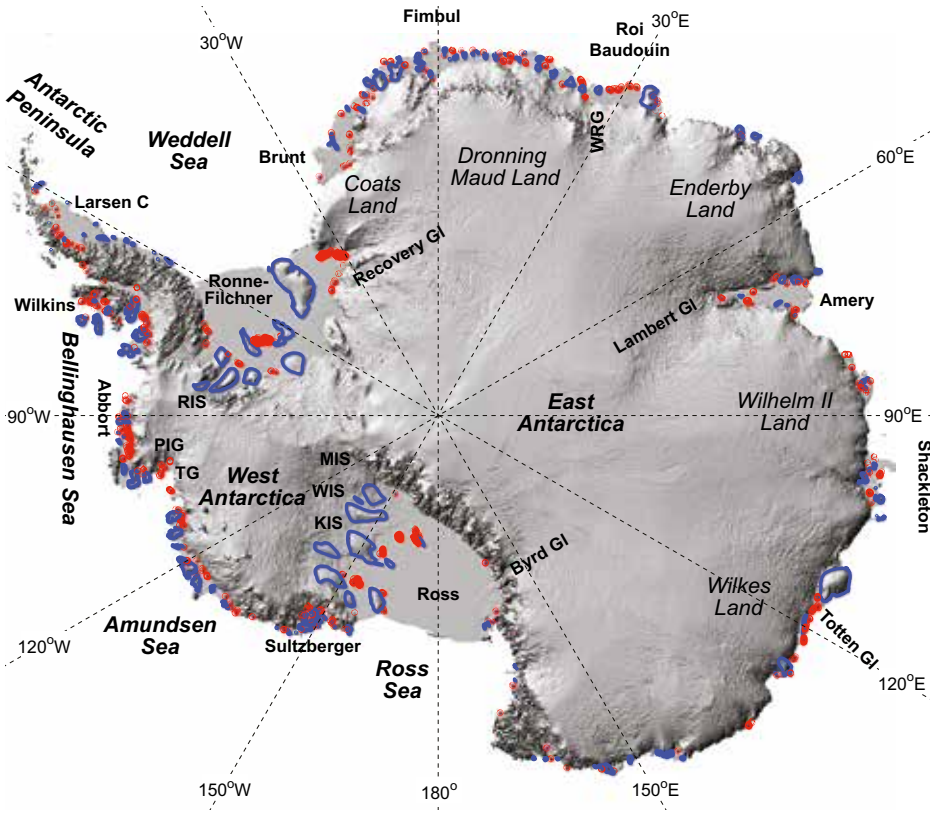
Our first inventory found that almost all Antarctica's ice shelves have ice rises and rumples. They are definitely small in size (typically less than 200 km^2), but big on impact: evidence shows that they play significant roles in Antarctic evolution, on various timescales.

The Antarctic coast facing the Atlantic and Indian Ocean sectors, called Dronning Maud Land (DML), has many small (<100 km wide/long) ice shelves fed by fast-flowing glaciers. These ice shelves are punctuated by numerous ice rises and rumples, and DML can be called an "ice rise garden". The number and location of ice rises and rumples in these ice shelves vary considerably, suggesting that individual ice rises play different roles, and that the evolution of adjacent regions is probably different as well, despite the same regional climate.

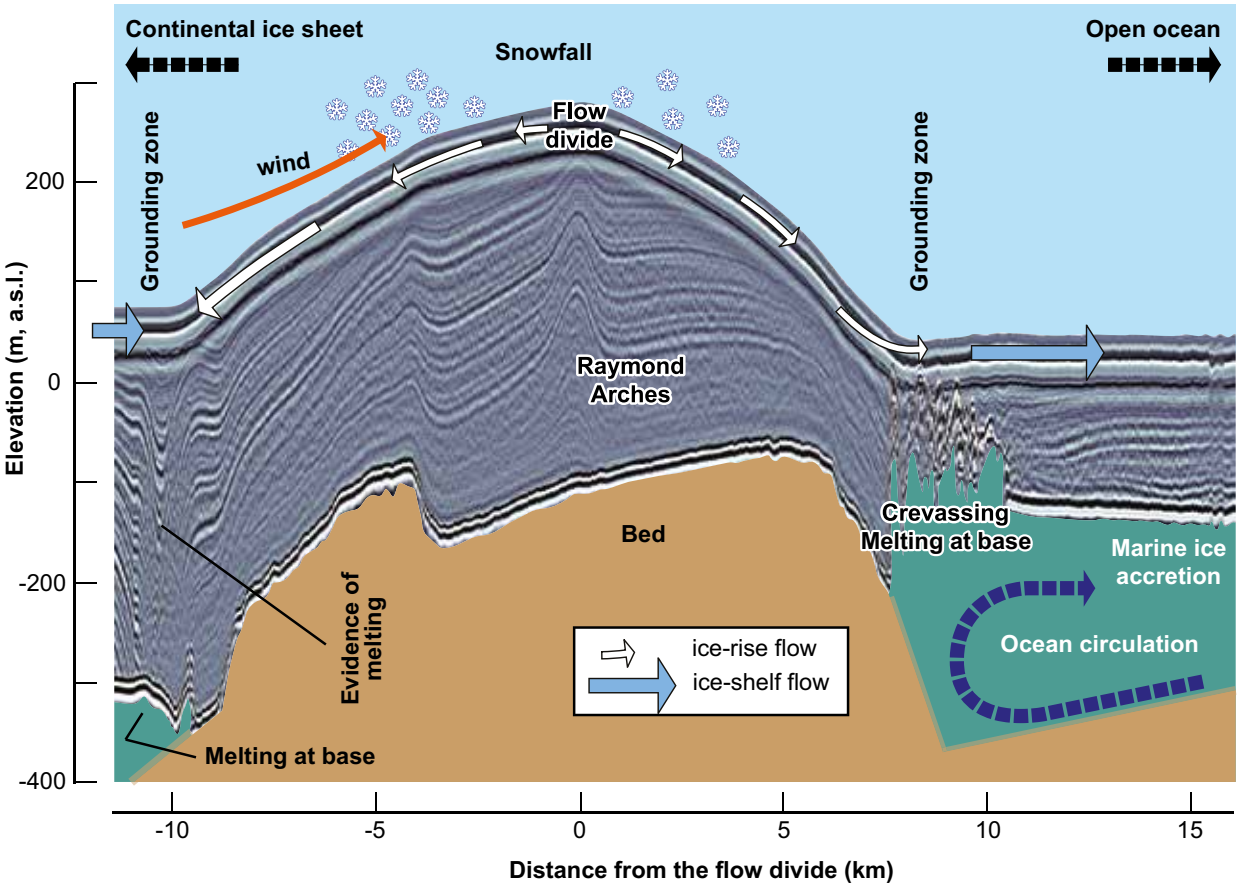
ICE LAYERS HINT ABOUT ICE RISE HISTORY

The evolution of an ice rise can be reconstructed with the help of ice-penetrating radar (see diagram). Like geological stratigraphy, ice stratigraphy detected with radar can often be associated with environmental

An ice rise viewed from an ice shelf. This ice rise is 30 km wide and 300 m high. Because it is surrounded by flat ice shelf, a distinct local climate appears near the ice rise. Our observations showed that surface mass balance (snowfall) changes by a factor of two or more over this small "hill" in the middle of the flat ice shelf. *Photo: Peter Leopold / Norwegian Polar Institute*



Distribution of Antarctic ice rises (blue, outlines) and rumples (red).



Cross section of an ice rise. Radar detects stratigraphy within the ice and the bed topography under the ice rise, but it cannot show seabed topography, as radio waves do not penetrate into the ocean. Both sides of the figure show floating ice shelves; the landward ice shelf (left) is held back by the ice rise and is therefore thicker, while the seaward ice shelf (right) is thinner and crevassed. Understanding the dynamic processes related the ice rise, including these thickening and thinning effects, is a major challenge in ice-rise research.

events, and its shape reflects past ice deformation. In particular, upward arches at the summit, called Raymond arches, can be used to diagnose whether the ice rise has thinned, thickened, or been in a steady state. More importantly, the presence of Raymond arches is strong evidence of stable summit position because they arise through summit-specific mechanisms.

Ice-penetrating radar developed at the Norwegian Polar Institute has been deployed to seven ice rises in DML: three ice rises in the vicinity of the Fimbul Ice Shelf as a part of the Norwegian Antarctic Expedition (NARE), two ice rises in the Roi Baudouin Ice Shelf, eastern DML, in collaboration with the Belgian Antarctic Research Expedition, and - most recently - two more ice rises in central DML in collaboration with India's National Centre for Antarctic and Ocean Research. These ice rises have distinct Raymond arches. Our analysis found that one ice rise in the eastern DML has been in essentially steady state over the past ~4000 years. Similar analysis is underway to reveal spatial variations of DML deglaciation history since the Last Glacial Maximum, about 20 000 years ago.

Karine Nigar Aarskog // UiT The Arctic University of Norway

The king of the wild

In the past decade, 230 animal trophies have been imported legally from Africa to Norway. Many of them were brought home by tourists. Tourists bagging animals in exotic places is nothing new: as early as the beginning of the 19th century, trophy hunters went to Svalbard.

One of the photographs that piqued Lena Aarekol's interest.
Photo: Giæver / Perspektivet Museum

Lena Aarekol is general manager of the Polar Museum in Tromsø.

She is interested in the history of trophy hunting in Svalbard.

Photo: Karine Nigar Aarskog / UiT The Arctic University of Norway

LENA AAREKOL, GENERAL MANAGER of the Polar Museum in Tromsø recently discovered a photo album that shed fascinating new light on trophy hunting as an aspect of early tourism to the Arctic.

"There are mentions of trophy hunting here and there, but very little has been written about it as a phenomenon in the Arctic", says Aarekol.

She is sitting with a pile of scans of old black-and-white photos showing various hunting parties in the Arctic. Ladies in long skirts and gentlemen in suits pose with dead polar bears they have just shot.

"Lord Lamont from England, for example. He rented a ship in Hammerfest in 1856 and went trophy hunting in Svalbard. The first organised cruise to Svalbard was in 1881 and there were some trophy hunters among the passengers", says Aarekol.

Intrigued by the photos, she has begun to investigate these people and their stories.

LIVE POLAR BEAR CUBS

Most of the ships that voyaged northward in the 19th century - to do research or catch food - took along hunters who paid good money for the opportunity to shoot wild animals and bring trophies back home. Most highly prized as trophies were polar bears, walruses and seals; some hunters bagged birds and reindeer. Many also went to Greenland to shoot musk ox. Sometimes the hunters took live polar bear cubs back with them and sold them to zoos on the mainland. The trips could last for up to three weeks, and the ships had a full crew that did most of the work, apart from firing the shot. That the hunters did themselves.

"These people were extremely wealthy, often from the United States, Germany, Austria or Great Britain. The high north was the last remaining white spot on the map, and they wanted to explore. Their motivation was the hunt itself and experiencing nature", says Aarekol. She compares trophy hunting in the Arctic with what currently takes place at southern latitudes, where hunters dream of shooting the largest, most imposing predator specimen.

"It's all about controlling nature and attaining a certain status. One American I write about in my research had also been trophy hunting in Africa and Asia. He compared the animals to figure out which presented the most difficult challenge. Earlier, his favourite had been the tiger, but after he had been to Svalbard, he changed his mind in favour of the polar bear", says Aarekol.

ANIMALS GIVEN STATUS AS PROTECTED

In 1904 Magnus Giæver established his own tourist company, operating out of Tromsø.

"His father owned whaling vessels and was engaged in whaling. On a trip to Novaya Zemlya they had along an Englishman who had purchased a berth on board in order to hunt birds. This might be how Giæver got the idea", says Aarekol.

Until the outbreak of the First World War, Giæver organised an average of one trip per year, and there were always trophy hunters among the passengers. 1907 was a peak year in terms of polar bear hunts. In that year alone, professional huntsmen and trophy hunters killed 888 polar bears in Svalbard. During the First World War, trophy hunting ceased because no one had time for that kind of activity. Interest waned further with the protection of reindeer in 1925 and walrus in 1952. The polar bear was given complete protection in 1973, putting an end to trophy hunting in Svalbard.

"With the protection of the polar bear it was all over; there was no longer any basis for going trophy hunting", says Aarekol.

She believes the trophy hunters in times gone by were motivated by the same aspirations that drive modern-day adventure tourism.

"They want to go out and discover something - to have an adventure. It isn't simply a matter of shooting and felling a prize, but of doing extreme things. So perhaps it is more a quest for adventure."

Ivar Giæver Krog, manager of Bennett Travel Agency Ltd., expressed it this way, in an article entitled "With a Norwegian Whaling Vessel to Svalbard and Erik the Red's Land", published in the magazine *Oslo illustrerte,* nr. 47, 23 November 1932. The article is perhaps a forerunner of the modern "infomercial".

> Compared to African safaris, which are more costly and expose the Traveller to dire threats of dysentery, malaria and other tropical diseases, hunting in pure Arctic air untainted by bacteria is like a visit to a sanatorium. The peculiar Arctic Landscape and the myriad light effects of the Midnight Sun create in themselves a Faerie Realm that always exerts a powerful attractive force on many of the Travellers who have frequented these Northern Shores.

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Tone Reiertsen // Norwegian Institute of Nature Research
Helge Markusson // Fram Centre

The Bird Cliff – a birdbrained scheme takes flight and soars

In the summer of 2016, the Norwegian Broadcasting System (NRK) broadcast "slow-TV" from the bird cliff at Hornøya in eastern Finnmark. What started out as a wild idea ended up being NRK Nature's largest production ever. This article takes you behind the scenes of "The Bird Cliff – Minute by Minute".

From the project's infancy more than two years ago, until it went off the air at the end of July last summer, it demanded much tender loving care from the participating scientists - both at the planning stage and during implementation. To support the project, a collaboration was established between scientists from the Norwegian Institute of Nature Research (NINA), the Fram Centre, Tromsø Museum, and NRK Nature.

FOCUS ON VULNERABLE SEABIRDS

Our objective was to disseminate knowledge about seabirds - how vulnerable they are and how changes in their populations reflect changes in marine ecosystems. In addition, we wanted to show how we do research on seabirds and how our country manages seabird populations. Norway has a huge national and international responsibility for seabirds. About 25% of all Europe's seabirds nest in Norway. Seabirds are the group of birds whose population decline is steepest and whose status on the endangered species list is worsening most rapidly, both nationally and internationally. The reasons are complex and not yet fully understood. If we are to follow up on Norway's great responsibility for seabirds, it is important that the public knows a bit about seabird biology, their conservation status, and what can cause changes in seabird populations. Through this collaboration with NRK, we wanted to create broad popular commitment to our seabirds.

HOW DID IT ALL WORK?

In the summer of 2016, Hornøya was transformed from a peaceful bird cliff at the edge of the Barents Sea to a TV studio full of cameras, cables, and microphones. Hornøya was chosen as a location partly because it is just a five-minute boatride from Vardø. In addition, most of our seabird species can be found here and it is more accessible than other bird cliffs.

"The Bird Cliff - Minute by Minute" reached out through several channels (TV, internet, radio, and social media), with the live broadcasts from Hornøya being the most important. These broadcasts ran round the clock for eight weeks over the Internet (nrk.no/piip) and as regular TV programmes for five weeks on both NRK1 and NRK2. There were 40 hours of TV broadcasts on NRK2 and five TV specials of about an hour each on NRK1.

An NRK team totalling 39 people worked on Hornøya throughout the five weeks. Twelve seabird researchers were involved to varying degrees - including both those who usually work on Hornøya and people

A puffin poses at the edge of the bird cliff.
Photo: Tone K. Reiertsen / NINA

from other bird cliffs in Norway. Their contributions consisted of everything from appearing on TV and giving expert commentary on the internet, to answering questions on chat forums and blogging on the forskning.no website under the heading "Sjøfuglbloggerne". There were some crowded and busy days on Hornøya and many hours in front of the TV cameras. In addition to NRK, Swedish television filmed and broadcast from Hornøya.

MEMORABLE MOMENTS

Life on a bird cliff changes a lot over the course of summer. Courting, nesting, and hatching provide plenty of variety and many memorable moments. However, three events stood out especially during NRK's broadcasts. First and foremost - always the highlight of a year on Hornøya - when the guillemot chicks jump from their nesting cliff, dozens of metres high. The chicks are at this point only a third of the

A puffin chick being tagged.
Photo: Signe Christensen Dalsgaard / NINA

The television cameras watched everything.
Photo: Tone K. Reiertsen / NINA

A black-legged kittiwake glides along the cliff face.
Photo: Tone K. Reiertsen / NINA

adult birds' size and cannot fly. Yet they jump off the cliff wall, often landing on sharp stones before they scramble past hungry and dangerous gulls to the ocean where the fathers are floating, calling to them and waiting for them. The chicks that reach the water in one piece follow their fathers into open waters, where (hopefully) they grow to adulthood. The guillemot jumping is spectacular. Often several thousand chicks jump on the same evening - it rains chicks and the noise at the foot of the bird cliff is deafening. During the TV broadcasts, we all had the opportunity to experience it.

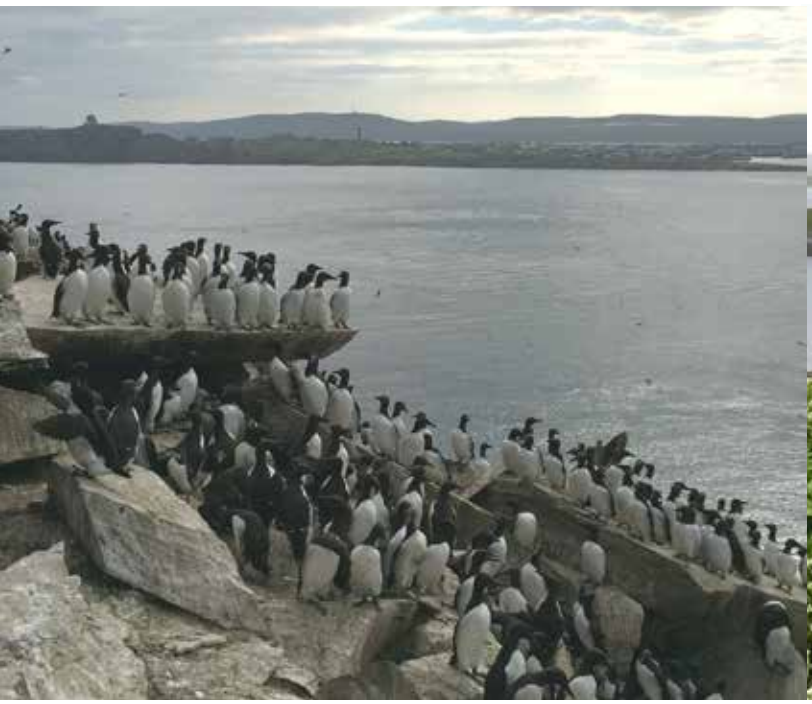
One evening we witnessed a battle between David and Goliath: a guillemot chick took on a great black-backed gull - and won. This particular guillemot chick had for some reason decided to jump on an evening when scarcely any other chicks were jumping. It was essentially doomed, almost certain to be eaten by the gulls that lurked beneath the cliff waiting for "chicky bits". A black-backed gull approached, bill gaping, confident about its next meal. But all it got was a flurry of quick jabs to the head. The guillemot chick launched a counterattack, and the black-backed gull was so surprised (or embarrassed) that it gave up and flew away.

Another highlight was when NRK managed to set up a small camera inside a puffin cave. This gave everyone the opportunity to follow the puffins' family life up close, in the otherwise so dark and inaccessible puffin cave. Few have previously had the privilege of seeing how the fluffy ball of wool that is a puffin chick behaves with its parents.

MANY LEARNING EXPERIENCES

Being part of "The Bird Cliff - Minute by Minute" provided masses of experience, primarily about dissemination via television: what works and what does not work. The slow TV format obliged us to give a running commentary in real time, almost like a sportscaster reporting on a live football match. This was a concept NRK Nature had never tried before - let alone how new it was to seabird researchers! It was a stunt, a gimmick, but at the same time, it was a precious gift to us scientists. We were allowed to talk about our research until we were hoarse. Participating in this project was both rewarding and fun.

Imparting knowledge on such a grand scale is demanding in terms of both time and money. In addition, it was all taking place during the nesting season - a time of year when seabird scientists are at their busiest, counting birds, ringing birds and collecting data. If the project was to succeed, we had to buy time off from our ordinary research duties and plan the fieldwork season to ensure that we had good assistants



Adult guillemots throng the cliffs. Vardø can be seen in the background.

Photo: Tone K. Reiertsen / NINA

A guillemot chick.

Photo: NRK

who could step in for us when we were busy. Fortunately, the Research Council of Norway and the Fram Centre provided the extra financing required.

GOOD RESEARCH DISSEMINATION: A CIVIC DUTY

Releasing research results through mass media channels can be a "scary" process. After talking with journalists, some scientists feel that their message has been distorted and presented differently from what they intended. As scientists, we tend to focus on exactly how reliable our results are and we often get stuck in dry data. This doesn't work well when you're chasing big headlines, so journalists may choose to "translate" our presentations and make them more attention-getting. As a result, scientists may be tempted to avoid this type of dissemination. *Trust* and *accessibility* are two keys to improving interactions between scientists and journalists. And those keys open doors in both directions.

During the bird cliff project at Hornøya, scientists and journalists were constantly accessible to each other, day and night and in all types of situations. Accordingly, all parties had good opportunities to toss ideas back and forth concerning the material to be presented. No articles were published until the people being interviewed had read them properly. All parties were pleased and trust was established.

All scientists know that in addition to doing good research and publishing our results in scientific journals, we must share the results of our research with the general public. In fact, we have a civic duty to disseminate. It is a long time since researchers automatically had the status of authorities and could comment or decline to comment solely by virtue of being researchers. Luckily, times have changed. Nowadays, most people have a lot of knowledge, and building on this knowledge is easier if new information is presented in a popular scientific manner. There has also been a shift in who makes decisions about what topics should be studied, from scientists deciding more or less for themselves to society shaping the research agenda through steering directives and guidelines. From this perspective, it is even more important that researchers and experts communicate about both the subject of their research and its importance.

In "The Bird Cliff - Minute by Minute", that is exactly what we were aiming for: both to present knowledge about seabirds and current seabird research, and to convey why it matters. Taking part in this ambitious outreach project felt in many ways like jumping off a cliff without being able to fly. But just as the guillemot chick had to jump, we too had to throw ourselves into the unknown. And we think we landed quite well in the end.

The Bird Cliff and Achim Randelhoff recognised with Fram Awards

The Fram Awards for 2016 went to one project and one individual. The award ceremony took place on Fram Day, 10 November, at the Fram Centre in Tromsø.

THE DISSEMINATION AWARD

Fuglefjellet (The Bird Cliff) received the Fram Centre's Dissemination Award for 2016.

The Bird Cliff is a project involving scientists from NINA – Norwegian Institute for Nature Research and UiT The Arctic University of Norway. The collaboration between the Fram Centre institutions and NRK Nature (the nature division of Norway's national broadcasting corporation NRK) resulted in "slow TV": five weeks of 24-hour transmission from the bird cliff at Hornøya outside Vardø. The transmissions were streamed on internet in Norway and Sweden, and there were daily television broacasts. As many as 1.8 million people followed the broadcasts in Norway in June and July. In addition, several websites – particularly nrk.no and forskning.no – focussed on research on seabirds and climate change. A major element of the project was direct contact between scientists and viewers by means of social media and blogs.

THE JURY'S MOTIVATION:

"The Fram Centre's Dissemination Award for 2016 goes to a dissemination project that has shown in an excellent fashion what superb quality research dissemination can attain when many scientists collaborate closely and communicate via a broad range of platforms. The outreach was carried out in close collaboration with the initiator, a professional production company; this helped ensure a final product that stands as a rock-solid example of broad and comprehensive "Fram Centre Dissemination".

"The project is a worthy recipient of this year's dissemination award."

THE RESEARCH AWARD

Achim Randelhoff, PhD student at UiT The Arctic University of Norway and the Norwegian Polar Institute, was recognised with the Fram Centre's Research Award for 2016.

Randelhoff's research interests include physical processes in water, such as vertical mixing and the flux of nutrient salts, and relations between physics and the biosphere in frozen waters. He also studies physical interactions at the boundaries between the atmosphere, sea ice, and the ocean.

THE JURY'S MOTIVATION:

"The Fram Centre's Research Award for 2016 goes to a scientist who is at an early stage of his career but has already published many important papers. By combining different disciplines, the recipient has helped close knowledge gaps and provided a basis for continued research with a cross-disciplinary focus and innovation. His research has already received international acclaim.

"This year's committee decision complies closely with the statutes by rewarding a young, up-and-coming scientist. He is an excellent representative for the work that supports and is done within one of the Fram Centre flagships."

From this year's award ceremony. Left to right: Nils Arne Sæbø (NRK Nature), Helge M. Markusson (Fram Centre), Achim Randelhoff (UiT The Arctic University of Norway), Tone Kristin Reiertsen (NINA – Norwegian Institute of Nature Research), Jenny Duesund (NRK) and Bjørg Bruset (NINA).
Photo: Trude Borch / Akvaplan-niva

Helge M. Markusson // Fram Centre

Scientists on an outreach tour

Meeting schoolchildren of all ages is important when disseminating research. In September, for the fourth year in a row, scientists from Fram Centre member institutions visited towns and villages in northern Norway in an event called "The Scientists Are Coming". They visited Kirkenes, Nordreisa, Målselv, Finnsnes, Harstad, and Narvik, as part of the National Research Days in 2016. This year's topics ranged from research into environmental pollutants and plastic litter to the story of how snowy owls live.

Perrine Geraudie from Akvaplan-niva spoke with a group interested pupils in Nordreisa, east of Tromsø.
Photo: Helge M. Markusson / Fram Centre

Photo: Helge M. Markusson / Fram Centre

Helge Markusson // Fram Centre

Nordic–French seminar at the Fram Centre

In October 2016, the French Institute of Norway and the French Embassy, together with the FRAM High North Research Centre on Climate and the Environment and UiT The Arctic University of Norway, arranged the workshop "Environment and Governance" at the Fram Centre in Tromsø.

The workshop was part of *The Changing Arctic*, a series of Nordic–French seminars addressing key arctic issues in the field of research. Other seminars in the series were arranged during 2016 in Denmark, Finland, Norway, and Sweden.

The Arctic region is undergoing rapid transformations due to global warming. Its natural resources attract various kinds of industries, from fisheries to renewable energy, while indigenous communities are facing socioeconomic changes. Protecting local cultures and preserving arctic ecosystems requires a deep understanding of the impact of human activities, as well as efficient governance across the whole region. Therefore, research issues concerning adaptation to climate change and resource management were discussed, with a particular focus on indigenous peoples. An important discussion topic was indigenous communities' participation in the construction of a sustainable Arctic, through their traditional knowledge and their political role.

The seminar had 70 attendees, among them His Excellency Jean-Francois Dobelle, French ambassador to Norway.

A public conference took place after the seminar: "Governance and traditional ecological knowledge in the Arctic: towards adaptation to a global change". It was presented by Marie Roué, of the National Museum of Natural History, Paris.

Jo Jorem Aarseth // Fram Centre

Is modern hardcore science up to the task?

The Nordic–French conference on research in the Arctic offered brilliant presentations by highly skilled researchers, and cast much-needed light on the value of and the need for traditional knowledge. This article shares the personal reflections of one listener.

Knowledge that is passed on for generations by indigenous and local communities is passed on for a reason: it works. Such knowledge is the key these communities use when adapting to changes in climate, resource abundance and availability, and has helped them sustain their lifestyle for thousands of years. In the modern scientific community – at long last – awareness and acceptance of this knowledge is growing. But traditional knowledge cannot be colonised by modern science. As scientists start to realise this, and recognise the value of traditional knowledge, it is becoming more common to involve local and indigenous communities in scientific projects, and to plan such projects with traditional knowledge as a basis.

Experience from scientific projects that incorporate traditional knowledge at an early stage points to the necessity of developing this link even more in the future. Hardcore science sometimes appears to be a hit-and-run operation. The researchers come to a community, do their work, then rush off to new projects and new deadlines, leaving the local people with no tangible benefits. Instead, the findings should be made understandable and available for traditional communities. This is a way of returning the favour, providing knowledge that may be useful and beneficial to the local community even after the project is completed. Scientists should be aware of the value of mutuality and focus on ensuring "win–win" situations, projects that will benefit both "sides" in the years to come. And scientists should be aware: *Bad science will not survive.*

Development of the Arctic is a common ground for the interested parties. Traditional communities want to sustain their lifestyle in the high north, while simultaneously opening up for industry and other sources of income – at least to some extent. Such new activities would create more jobs and greater welfare. Yet this needs to be done with an acceptable environmental footprint for the areas in question. Achieving this requires cooperation on all levels: national and international, between regions and industries, between scientists and the local community.

Environmental management and political responses play important roles in the development of areas in the high north and Arctic. To guide this process in the right direction, both need to be flexible and dynamic. Sometimes management strategies need to be changed and adopted on short notice. The voices of the local communities should be trusted and heard in this respect.

The Fram Centre especially wants to thank Institut Français d'Oslo and the French Embassy to Norway for organising the seminar. Hosts were UiT The Arctic University of Norway and the Fram Centre.

Ole Magnus Rapp

Can we handle the consequences of climate change? Report from Fram Day

Short, mild winters without snow. More unpredictable weather with more precipitation and more wind. By 2100, maybe farmers in northern Norway will be able to grow grapes. Are we prepared for Tromsø having the same climate as the south of France does today? Climate researchers say: "Definitely not!"

Professor Rolf Anker Ims at UiT The Arctic University of Norway is a veteran of climate research and is head of a comprehensive project measuring changes in the arctic environment. He is frustrated about how little effort is being made towards meeting future challenges.

"The climate is changing nature very quickly, and we have to keep up. In 80 years' time, the climate of current-day France may be the climate of Tromsø. We must prepare for this", he says.

"I am afraid that research in Norway is not equipped to deal with the challenges that come with climate change. Today we are unable to predict all the consequences", says Ims. He was one of approximately 170 scientists, administrators and a few politicians who gathered at the annual Fram Day to discuss the utility of current research for society.

LONG-TERM PERSPECTIVE CRUCIAL

Many participants nodded their agreement to Ims' presentation. Scientists lack long-term funding for monitoring of changes in nature over time.

"Typically, funding is allocated for only three or four years, and this provides poor conditions for good climate research", says Rolf Anker Ims. He emphasises that predictability is a prerequisite for carrying out long measurement series.

A broad range of research institutions in Tromsø would like to see ministries other than the Ministry of Climate and Environment commit to financing ongoing research. The Ministry of Trade, Industry and Fisheries and the Ministry of Education and Research are among those being urged to show greater interest.

WANT TO KEEP DECISION-MAKERS INFORMED

The experts also wish that more of the people who make political decisions – for instance those who work with the Ministry of Foreign Affairs – would listen to their research results first.

"Shorter funding horizons mean that we scientists produce ephemera, that make us look good in the eyes of those who like to go by publication figures. But we don't have the resources we need to give the best expert advice on the effects of changes in climate", says Rolf Anker Ims.

He himself leads a major research programme that monitors changes in nature. Over the course of a short time, scientists see that plains and mountain plateaus are becoming overgrown; the lemming population may not peak, which poses a threat to raptors and the arctic fox. New and greedier species of leaf-eating caterpillars will lay to waste tens of thousands of square kilometres of forest; the permafrost will let go of the tundra, releasing methane gas and increas-

Standing outside the Fram Centre, Rolf Anker Ims (left) says: "We scientists don't have enough resources to predict the consequences of climate change." Norunn Myklebust (centre) and Jan Gunnar Winther (right) are of the opinion that the authorities must increase the funding for climate research.
Photos: Ole Magnus Rapp

ing the speed of climate change. Rolf Anker Ims is pleased that the Fram Centre's research has yielded good results despite inadequate funding, but he would like increased resources and long-term frameworks for research.

OTHER VOICES FROM THE FRAM CENTRE

Jan-Gunnar Winther, director of the Norwegian Polar Institute, pointed to the Fram Centre as a jewel of commitment to competence. However, he agrees with Ims that much remains to be done.

"We aren't prepared for long-term, dynamic research that is able to predict future challenges. There is also room for improvement in interdisciplinary research collaboration", he says. At the same time, Winther points out that the research community in Tromsø does good work, and produces results; without this expert community in the northern part of the country, Norway would have a far weaker position, for example in international climate negotiations.

"There is also a huge untapped potential between what industry and commercial enterprise needs, and what academia delivers", says Winther.

Norunn Myklebust, director at the Norwegian Institute for Nature Research, points out that we are well equipped for the challenges of the future; among other things, the quality of the research and its utility for society is high.

"But there isn't enough funding. The Fram Centre, and all its member institutions, must also strengthen their outreach activities to spread their knowledge about climate issues."

Mette Ravn Midtgard, senior scientist at SINTEF, also called for broader research. She believes that a search for climate consequences in local communities and regions might lead to many interesting results.

"The natural sciences are strong at the Fram Centre. But we represent a broad selection of institutions and we should strengthen our interdisciplinary contacts", says Anita Evenset, head of research at Akvaplan-niva.

ENTERPRISE AND ENVIRONMENTAL INTERESTS

Christian Chramer, regional director of NHO (the Confederation of Norwegian Enterprise) called for closer connections between research and industry. He would like to see more research leading to start-up companies, and called for meeting places for industry and research.

Sigurd Enge from the Bellona Foundation, a non-profit organisation focussed on the environment, believes we are at the edge of an arctic precipice, and that many things are going very badly.

"A few years ago, the Arctic was one giant hole in our knowledge. Now we know a little, but there is still a lot to learn about climate change, erosion, pollutants, ice and air. Svalbard is now 10-15 degrees warmer than normal and we don't know enough about what is vulnerable in the time ahead", he said.

Enge thought climate research involved too much back patting among scientists, and wanted to get the research results out to the people who need them.

Helge M. Markusson // Fram Centre

Open Day at the Fram Centre drew over 1000 visitors

To stimulate interest in the research and other activities going on at the Fram Centre: this was the main objective of the event "Fritt Fram!" The Open Day was organised for the first time in and around the Fram Centre, Polaria and the MS Polstjerna on 1 October 2016. The event attracted more than 1000 visitors, and all the institutions represented in the Fram Centre building had stands and activities.

The biggest attraction was the large outdoor stand dealing with the problems related to plastic in oceans. Divers from the Tromsø Student Diving Club collaborated with scientists and environmental managers to shed light on this topic. The divers retrieved huge amounts of rubbish from the bottom of Tromsøysund, the fjord right beside the Fram Centre.

"The event is part of the revitalisation of the National Research Days in Tromsø. After more than fifteen years of events on Strandtorget in Tromsø, we felt the need for renewal. This also entails close collaboration with UiT The Arctic University of Norway; they organised their Open Day the day after "Fritt Fram!" On the basis of our experiences, we can state categorically that we will be doing this again", says Helge M. Markusson, Outreach Coordinator at the Fram Centre.

All photos: Ann Kristin Balto / Norwegian Polar Institute


IC IS HOT

Ivar Stokkeland // Chief Librarian, Norwegian Polar Institute

New books in 2016

Some interesting recent additions to the Norwegian Polar Institute Library

The Serengeti Rules: The Quest to Discover How Life Works and Why It Matters

Sean B. Carroll. Princeton Univ. Press. 263 pp.

Carroll asks the big biological questions about how life works. How does nature produce the right numbers of lions and zebras on the savanna? How does your body produce the right numbers of all its different types of cells? In this book, Carroll shows the fundamental connections, how nature is regulated by certain principles that apply to everything from molecules to macro-ecological systems. The logic of life.

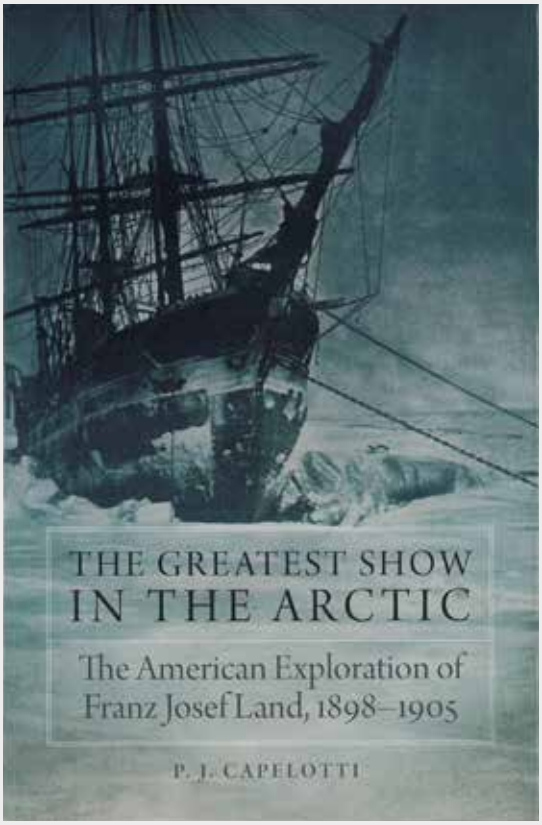
He constructs his explanation by telling the exciting story about how pioneers in different medical and biological fields arrived at major breakthroughs in their research. But what does this book have to do with the Arctic? Well, the Englishman Charles Elton has an entire chapter (The Economy of Nature), that is inseparably linked to Svalbard.

At the age of 21, Elton was a member of the First Oxford University Spitsbergen Expedition as a zoologist. The young scientist was terribly seasick on the journey north and was "medicated" with spirits. On arrival in Spitsbergen, the raucously bellowing Elton was carried ashore with the rest of the luggage. He quickly recovered and began investigating Svalbard's insects and nature with his colleagues. While they were still in Svalbard, Elton initiated lab experiments examining, among other things, the freeze-tolerance of crustaceans. When they had to shoot a polar bear, Elton was disappointed not to find any parasites on it.

When he returned home, Elton analysed the zoological material. There were relatively few animal species in Svalbard, yet from his material, Elton constructed the first food-web map of a complex ecosystem. Just two years later, Elton was chief scientist on a new Svalbard expedition. On the way home, they stopped in Tromsø. Elton popped into one of the small town's bookshops and found Collett's "Norway's Mammals". Basically, he was unable to read Norwegian and was forced to acquire a dictionary, but he later declared that the book changed his life.

Elton was fascinated by Collett's detailed description of "lemming cycles", with population spikes about every four years. He drew diagrams of lemming population fluctuations, tried to find patterns, and expanded his system to species such as arctic fox, short-eared owl, Canadian rabbit, lynx, and peregrine falcon. At that time zoology held that animal populations were largely stable. Elton realised that this was incorrect.

He gathered his new ideas in his book "Animal Ecology" (London, 1927), thus laying the foundation for modern ecology. After Elton had turned eighty, he wrote a personal account of the 1921 expedition. This can be found in its original binders in the Norwegian Polar Institute's library; we have also posted it in our digital archive.



South Pole: Nature and Culture

Elizabeth Leane. Reaktion Books. 232 pp.

This well-written and well-illustrated book introduces us not just to the research being done at the South Pole and in Antarctica, but also to Antarctic politics, mythology, exploration history and a lot more. Leane is professor of literature at the University of Tasmania.

The Greatest Show in the Arctic: the American Exploration of Franz Josef Land, 1898-1905

P.J. Capelotti. University of Oklahoma Press. 645 pp.

I have mentioned Professor Capelotti before in this column. This time he has delivered a very thorough and readable work about the American exploration of Franz Josef Land more than a hundred years ago. Here we meet the extravagant characters Walter Wellman, Evelyn Briggs Baldwin, Anthony Fiala, Russell W. Porter and William Ziegler. And we meet their Scandinavian counterparts with names such as Paul Bjørvig, Bernt Bentsen and Carl Johanson.

In an impressive manner, Capelotti has collected all the available knowledge about these three expeditions, from their spectacular financing to their "bitter ends". In conjunction with his work on this book, Capelotti has also amassed a unique collection of old/pre-Soviet place names in Franz Josef Land.

Ishavsfarerne, 1859-1909

Kjell-G. Kjær. Stamsund: Orkana. 538 pp.

In line with tradition, we also include a Norwegian title. Over the years, Kjær has meticulously gathered a truly unique material about ships that have plied the polar seas. This work has previously led to a number of articles in "Polar Record" and in a comprehensive ship register (digitally accessible at the Norwegian Polar Institute). In this impressive work, Kjær tells the history of the everyday heroes who worked in the Arctic Ocean.

He describes events momentous and minor, gives us a thorough overview of conflicts, technological developments, and what sorts of industry were based on raw materials from the Arctic. Of particular value for those interested in the history of the Arctic is an extensive "cast of characters" with biographical data.

Ice-cold sweatshop in Franz Josef Land

Ann Kristin Balto // Norwegian Polar Institute
Photo: Anthony Fiala // Norwegian Polar Institute photo archive

"All hands to work. There is sewing to be done and equipment to be repaired!" Was this the order barked out by Anthony Fiala in the tiny hut on Rudolph Island, in the northeastern Barents Sea? Far from civilisation in an improvised sewing workshop, eight men are hard at work in the light from several oil lamps. The Norwegian Sigurd Myhre is using one of the two sewing machines; seven other men ply stout needles on reindeer hides. The clock on the wall stands at ten past four. We must go back in time more than a hundred years, to 1903. The race to the North Pole has started. The previous year an American expedition attempted to reach the North Pole from Rudolph Island (the northernmost island of Franz Josef Land). Now Anthony Fiala is back as leader of the expedition to make a new attempt to reach the Pole.

It is destined to be a gruelling enterprise. In the first autumn, their ship *America* is crushed in the pack ice and sinks. Their lifeline back to civilisation is severed. Despite the setback, they try to reach the North Pole, making three attempts with dog teams and ponies. The weather and difficult conditions soon force them to turn back. They have a salvage agreement and in the summer of 1904, Fiala and 25 of the men go 265 km south to Cape Flora. The summer passes, and there is no sign of a ship. They are obliged to stay for one more winter, this time without preparation. Russell W. Porter writes in his diary:

There is hunger here, every day, yes, every hour... there is cold and sickness, for how can the body withstand such low temperatures on such insufficient nourishment? There is uncleanliness, for there is no soap; and there are fights and agreements to disagree, and through all, that disquieting and depressing thought of failure, of good intentions gone wrong.

We believe that this photo was taken during the first autumn, before animosity, food shortage and cold had sown discontent among the crew. In the summer of 1905, the two parties were rescued, both those who had spent the winter on Cape Flora and those who remained on Rudolph Island. It took the ship *Terra Nova* under her Norwegian master Captain Kjeldsen six weeks to force her way through the pack ice to the shipwrecked men.

Projects in the Fram Centre Flagships for 2016

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
Effects of climate on cod life history and ecology along a temperate-arctic gradient	Hector Andrade	ApN, IMR, UNIS, UT, BC	hector.andrade@akvaplan.niva.no
Effects of oceanic inflow and glacial runoff on fjord circulation in Kongsfjorden, Svalbard; establishment of a high resolution ocean circulation model system	Arild Sundfjord	NPI, IMR, UNIS	arild.sundfjord@npolar.no
The role of the harbour porpoise	Ulf Lindstrøm	IMR, UiT, ApN, NAMMCO, NTNU, UoStA	ulf.lindstroem@imr.no
How do a dominant predator and climate shape fish biodiversity over space and time in large marine ecosystems?	Kari Ellingsen	NINA, IMR, UiT, PINRO, BedIn, MU	kari.ellingsen@nina.no
The invasive red king crab as a stressor on coastal marine food webs	Jan Sundet	IMR, UiT	jan.sundet@imr.no
Seabird habitat use and migration strategies	Børge Moe	NINA, ApN, UiT, NILU, UNIS, NPI, NTNU, UoO, CNRS, LRU, UoGr, IMARES, AU, AARI, UoF, CEH, BAS, UAF, UoIs, UTu	borge.moe@nina.no
The coastal migratory behavior of anadromous fish	Guttorm Christensen	ApN, UiT, NIVA, FOC, UoWa	gnc@akvaplan.niva.no
Costal heritage for sustainable regional development	Einar Eythorsson	NIKU, NORUT, TCD	einar.eythorsson@niku.no
Timing of reproduction in seabirds	Zofia Burr	UNIS, NPI, NINA, UiT, ApN, IMR, BS	zofia.burr@gmail.com
Ecological and commercial implications of extreme winter arrivals of herring and whales into North-Norwegian fjord systems	Martin Biuw	ApN, NINA, UiT	mab@akvaplan.niva.no
Mapping sea ice characteristics	Sebastian Gerland	NPI, MET, NORUT, UiT	sebastian.gerland@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, IMR, ApN, NBIC	hartvig.christie@niva.no
Salmon at sea in a changing world	Martin Svenning	NINA, UiT, LUKE, UTu, FOC, UoWa	martin.svenning@nina.no
Carbon flux dynamics in ice-free versus icecovered Svalbard fjords during the last decade: Exploring the effects of sea ice variability on the downward flux of biogenic particles	Gerald Darnis	ApN, UiT, UNIS, NPI, UoLa, SAMS	gerald.darnis@akvaplan.niva.no
The Arctic scallop *Chlamys islandica* as a biosensor for detection of effects of climate upon ecosystem functioning and anthropogenic impact in Svalbard	Lionel Camus	ApN, UiT, CNRS	lionel.camus@akvaplan.niva.no
Life on the edge - Blue mussels on Svalbard	Jørgen Berge	UiT, ApN, UNIS, BC	jorgen.berge@uit.no
An integrated approach to understanding weather–ocean interactions along seabird feeding routes	Kjell Einar Erikstad	NINA, IMR, BS, NTNU, UoR	kjell.e.erikstad@nina.no
Direct age determination in crustaceans: Validation of periodicity of age bands in Barents Sea red king crabs	Bodil Bluhm	UiT, ApN, UNIS, BC, UoNB	bodil.bluhm@uit.no
Marine base maps for the Porsanger Fjord	Aivo Lepland	NGU, IMR, NRPA	aivo.lepland@ngu.no
Climate driven regime shifts in arctic rocky bottom	Raul Primicerio	UiT, ApN, UNIS	raul.primicerio@uit.no
High latitude fjord ecosystems	Torild Johansen	IMR, ApN, UiT	torild.johansen@imr.no
Meroplankton biodiversity	Janne Søreide	UNIS, ApN, UoGd, PAS	janne.soreide@unis.no

Sea ice in the Arctic Ocean, Technology and Governance (Arctic Ocean)

Sea ice, ecosystems and models

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Developing modelling tools to understand the role of solar radiation in sea ice mass balance in a seasonally ice covered Arctic	Mats Granskog	NPI, MET, UiT, ApN, FMI, CRRL, AWI	mats.granskog@npolar.no
Long-term variability and trends in the Atlantic water inflow region	Sebastian Gerland	NPI, IMR, UNIS, UiT, PAS, WHOI	sebastian.gerland@npolar.no
Mesoscale modeling of ice, ocean and ecology of the Arctic Ocean	Tore Hattermann	ApN, IMR, NPI, SINTEF, MET	tore.hattermann@akvaplan.niva.no
Ecosystem modeling of the Arctic Ocean around Svalbard	Pedro Duarte	NPI, ApN, NIVA, UiT	pedro.duarte@npolar.no
Holocene ocean and sea ice history at north-east Svalbard - from past to present warm extremes	Katrine Husum	NPI, UiT, UNIS, BAS, NCAOR	katrine.husum@npolar.no
Using tracers, atmospheric indices and model output to explain changes in the Arctic Ocean inflow and outflow through Fram Strait	Paul Dodd	NPI, NRPA, ApN, IMR, OASYS	paul.dodd@npolar.no

Driving forces and development of new industry

Shipping in the Arctic - drivers and forecasts	Eirik Mikkelsen	NORUT, NCA, Capia.no, UiT, FNI, ApN	Eirik.Mikkelsen@norut.no
Information systems in the Arctic Ocean: Drivers, architecture, and effects on the development of marine economic activities	Maaike Knol	UiT, NPI, MET, WU, SCNN	maaike.knol@uit.no

Technology

Ice floe interaction with ships and waves	Karl Gunnar Aarsæther	SINTEF, UiT, TO, Opilio Inc.	Karl.Gunnar.Aarsather@sintef.no

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

Understanding the physical and chemical mechanisms controlling ocean acidification (OA) in Arctic waters – past, present and future

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Current OA state and variability	Agneta Fransson	NPI, NIVA, IMR, UiT, UNIS, BedIn	agneta.fransson@npolar.no
Biogeochemical drivers and climate change on OA	Agneta Fransson	NPI, IMR, UoH, BedIn	agneta.fransson@npolar.no

Biological effects of Ocean Acidification (OA)

Physiological challenges of OA on copepods	Howard Browman	IMR, NPI, BOS, UoM, CU, RU	howardb@imr.no
Transgenerational effects of OA	Claudia Halsband	ApN, NPI	claudia.halsband@akvaplan.niva.no
Evolutionary adaptation during Arctic OA	Peter Thor	NPI, ApN, UNIS, UQAR, UoGo, DTU	peter.thor@npolar.no
Ontogeny and physiological constraints on early life history stages of *Lophelia pertusa*	Johanna Järnegren	NINA, FSU	johanna.jarnegren@nina.no
Pteropod shell thickness and composition in different regimes	Agneta Fransson	NPI, IMR, JAMS-TEC, PAS	agneta.fransson@npolar.no

Coupled climate-ecosystem-acidification modelling from organism to basin

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Validation and comparison of coupled physical-biogeochemical models	Philip Wallhead	NIVA, IMR	philip.wallhead@niva.no
Investigate pelagic ecosystem sensitivity and feedbacks to Arctic OA	Philip Wallhead	NIVA, IMR	philip.wallhead@niva.no
Population-level effects of Arctic OA on copepods	Pedro Duarte	NPI	pedro.duarte@npolar.no
Benthic-pelagic coupling of Arctic OA	Evgeny Yakushev	NIVA	evgeny.yakushev@niva.no

Socio-economic consequences and management options

Socio-economic consequences and management options of OA	Eirik Mikkelsen	NORUT, UiT, NIVA, UoQ	eirik.mikkelsen@norut.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
After-the-Pest: Ecosystem transitions following insect pest outbreaks induced by climate change in the European high North	Jane Uhd Jepsen	NINA, UiT	jane.jepsen@nina.no
Long term vegetation change in alpine areas in Northern-Norway and Poland – relation to climate and grazing	Jutta Kapfer	NIBIO, UiT, RAS	jutta.kapfer@nibio.no
Moose in Finnmark - spatial ecology and management in a changing landscape	Rolf Rødven	NIBIO, NINA, UiT	rolf.rodven@nibio.no

Ecosystem effects of extreme climate events and changing seasons

Use of remote sensing for increased precision in forage production	Marit Jørgensen	NIBIO, NORUT, UiT	marit.jorgensen@nibio.no
Ecosystem stress from the combined effects of winter climate change and air pollution – how do the impacts differ between biomes?	Jarle W. Bjerke	NINA, MET, NORUT	jarle.werner.bjerke@nina.no
Sentinel synergy framework – satellite observation of growth seasons in alpine and Arctic ecosystems	Eirik Malnes	NORUT, NINA, UiT	Eirik.Malnes@norut.no
Effect of climate extremes on inland production of grass in North-Norway	Gregory Taff	NIBIO, NINA	gregory.taff@nibio.no
Phenological synchrony of arctic plants and their pollinators at altered snow regimes at Svalbard	Elisabeth Cooper	UiT, NINA	elisabeth.cooper@uit.no

Capacity for adaptation in indigenous people and local societies

Territoriality - mobility and fragmentation in the reindeer husbandry	Marius Warg Næss	NIKU, NINA	marius.naess@niku.no
Integrative studies of pastoral societies ability to adapt rapid climate and ecosystem changes	Stine Barlindhaug	NIKU, UiT, NMBU	stine.barlindhaug@niku.no

Adaptive management of ecosystem services

Adaptive goose management beyond borders	Ingunn Tombre	NINA, NIKU, NORUT	ingunn.tombre@nina.no
Sustain – climate changes and effects on species important for ecosystem services	John-André Henden / Sandra Hamel	UiT, NPI, NINA	john-andre.henden@uit.no sandra.hamel@uit.no
Effects of climate changes on the use of ecosystem services by the local society	Vera Hausner	UiT, NINA	vera.hausner@uit.no

Observation systems for climate effects

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

Outreach

TundraSchoolnet extended – Research-based activities for schools in northern areas	Ingrid Jensvoll	UiT, NINA	ingrid.jensvoll@uit.no

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

The effects of contaminants on human health and Arctic communities

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Dioxins in reindeer and reindeer herders (and their families) from Sør-Varanger – lessons learned and risk management in theory and practice	Torkjel Sandanger	NILU, UiT, NORUT, ApN, TI, UoOu	torkjel.sandanger@uit.no torkjel.sandanger@nilu.no
Human biomonitoring and mechanistic modelling of organic compounds across time (1986-2007) in 30 year old Tromsø men	Linda Hanssen	NILU, UiT, ApN, UNN, INSPQ	linda.hanssen@nilu.no

The fate and effects of contaminants in Northern ecosystem in combination with climate change, natural and anthropogenic stressors

From FRAM research to sound policy making: Assessment of siloxane use and its potential risk to Arctic environments	Nicholas Warner	NILU, ApN, UoL, SU	nicholas.warner@nilu.no
Climate mediated increases in organic matter export to arctic coastal waters	Amanda Poste	NIVA, ApN, UiT, NPI, Salt.nu, UoO	amanda.poste@niva.no
Impacts of environmental contaminants and natural stressors on northern raptors	Jan Ove Bustnes	NINA, NILU, NTNU, UiT, UoA, AU, UoMu	jan.o.bustnes@nina.no
Multi-stress relationships in seabird populations: interactions between natural stressors and environmental contaminants	Jan Ove Bustnes	NINA, NPI, NILU, ApN, UoO, CEBC	jan.o.bustnes@nina.no
Microplastics in arctic marine food chains; biological uptake pathways and socio-economic consequences	Claudia Halsband / Dorte Herzke	ApN, NIVA, NILU, IMR, NINA, NORUT, NPI, UNIS, Salt.nu, TM	claudia.halsband@akvaplan.niva.no dorte.herzke@nilu.no
Contaminant levels and effects in killer (*Orcinus orca*) and humpback whales (*Megaptera novaeangliae*) present in Northern-Norway	Jenny Bytingsvik	ApN, NIVA, NILU, UiT, IVM, VU	jby@akvaplan.niva.no
Is the immune defense of Arctic charr in Lake Ellasjøen, Bjørnøya, compromised by their pollutant burden?	Even H. Jørgensen	UiT, ApN, NILU, UoCa	even.jorgensen@uit.no

Impact from industrial development and urbanization in the North - Fate and effects of pollutants on Arctic ecosystems

Transformation properties and environmental risk-pharmaceuticals	Roland Kallenborn	NMBU, UNIS, NILU, NORUT, NPI, ApN, SRCES-RAS	roland.kallenborn@nmbu.no
Single and mixture exposure of key Arctic contaminants (POPs, heavy metals and PAHs) in Icelandic scallops (*Chlamys islandica*) using in vitro approach	Perrine Geraudie	ApN, NIVA, NILU, IDAEA-CSIC, LIENSs	pge@akvaplan.niva.no
Impact of Arctic urbanization on the occurrence of new "urban" contaminants in the Norwegian Arctic	Pernilla Bohli Nizzetto	NILU, NIVA, ApN, RECETOX	pbn@nilu.no

Risk governance - Communicating and applying research results

Case Orrefjell	Louise Kiel Jensen	NRPA, NORUT, NMBU, NGU	louise.kiel.jensen@nrpa.no
Bringing the Arctic perspective to global conventions – The role of science in the negotiations towards the adoption of the Minamata Convention	Froukje Maria Platjouw	NIVA, ApN, UiT	fmp@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
Mapping and monitoring cultural heritage sites and environments in the Svalbard Archipelago	Stine Barlindhaug	NIKU, NINA, NORUT, NPI	stine.barlindhaug@niku.no
Net environmental benefit analysis tool to assess the environmental effects of Arctic oil spills and oil spill response technologies	Lionel Camus	ApN, UiT, NPI, UNIS, Cedre, UoLa	lionel.camus@akvaplan.niva.no
Ecosystem vulnerability assessment of resources in the Ecosystem vulnerability assessment of resources in the Barents Sea	Raul Primicerio	UiT, IMR, ApN	raul.primicerio@uit.no
Ocean Health in Transition	Per Fauchald	NINA, UiT, NIVA, IMR, NORUT	per.fauchald@nina.no

Consequences for organisms and ecosystems

Development of model for prediction of eutrophication and sedimentation from fish cage farms	Ole Anders Nøst	ApN, NIVA, UiT, NORUT	ole.anders.nost@akvaplan.niva.no
Fate and impact of mine tailings on marine Arctic ecosystems	Anita Evenset	ApN, NGU, IMR, NORUT, NRPA, SIO, UoG	anita.evenset@akvaplan.niva.no
Arctic Cetaceans and Ocean Noise	Kit Kovacs	NPI, UiT	kit.kovacs@npolar.no
Mineral extraction in the high North – radiological risks, impacts and mitigation	Louise Kiel Jensen	NRPA, NIVA, NMBU	louise.kiel.jensen@nrpa.no

Consequences for cultural heritage and society

Sea urchin harvest: Ecosystem recovery, integrated management of social-ecological system, ecosystem service and sustainability	Wenting Chen	NIVA, UiT, Nofima, UoC	wenting.chen@niva.no
The impact of extractive industries and tourism on socioecological dynamics in the Arctic	Vera Hausner	UiT, NINA	vera.hausner@uit.no
Ecosystem services and coastal governance	Einar Eythorsson	NIKU, Nofima	einar.eythorsson@niku.no

ABBREVIATIONS

AARI: The Arctic and Antarctic Research Institute; **ApN:** Akvaplan-niva Inc.; **AU**: Aarhus University; **AWI**: Alfred Wegener Institute; **BAS**: British Antarctic Survey; **BC**: Bates College; BedIn: Bedford Institute; **BOS**: Bigelow Laboratory for Ocean Science; **BS**: The Bjerknes Centre; **CEBC**: Centre d'Etudes Biologiques de Chizé; Cedre: Centre of Documentation, Research and Experimentation on Accidental Water Pollution; **CEH**: The Centre for Ecology & Hydrology; **CNRS**: The National Center for Scientific Research; **CRRL**: Control/Robotics Research Laboratory (NYU Polytechnic School of Engineering); **CU**: Clemson University; **DTU**: Technical University of Denmark; **FMI**: Finnish Meteorological Institute; **FNI**: Fridtjof Nansen Institue; **FOC**: Fisheries and Oceans Canada; **FSU**: Florida State University; **IDAEA-CSIC**: Institute of Environmental Assessment and Water Research – Spanish Council for Scientific Research; **IMARES**: Institute for Marine Resources & Ecosystem Studies; **IMR**: Institute of Marine Research; **INSPQ**: Public Health Expertise and Reference Centre - Québec; **IVM**: Institute for Environmental Studies; **JAMSTEC**: Japan Agency for Marine-Earth Science and Technology; **LIENSs**: Littoral, Environment and Societies, La Rochelle University; **LRU**: La Rochelle University; **LUKE**: Natural Resources Institute Finland; **MET**: The Norwegian Meteorological Institute; **MU**: Massey University; **NAMMCO**: North Atlantic Marine Mammal Commission; **NBIC**: Norwegian Biodiversity Information Centre; **NCA**: The Norwegian Coastal Administration; **NCAOR**: National Centre for Antarctic and Ocean Research; **NGU**: Geological Survey of Norway; **NIBIO**: The Norwegian Institute of Bioeconomy Research; **NIKU**: The Norwegian Institute for Cultural Heritage Research; **NILU**: Norwegian Institute for Air Research; **NINA**: Norwegian Institute for Nature Research; **NIVA**: Norwegian Institute for Water Research; **NMBU**: Norwegian University of Life Sciences; 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; **OASYS**: Ocean Atmosphere Systems - Research; **PAS**: Polish Academy of Sciences; **PINRO**: Polar Research Institute of Marine Fisheries and Oceanography; **RAS**: Russian Academy of Sciences; **RECETOX**: Research Centre for Toxic Compounds in the Environment; **RU**: Ryerson University; **SAMS**: The Scottish Association for Marine Science; **SCNN**: Science Centre of Northern Norway; **SINTEF**: The Company for Industrial and Technological Research; **SIO**: Scripps Institution of Oceanography; **SRCES-RAS**: Scientific Research Center for Ecological Safety - Russian Academy of Sciences; **SU**: Stockholm University; **TCD**: Trinity College Dublin; **TI**: Thule Institute; **TM**: Tromsø Municipality; **TO**: Troms Offshore; **UAF**: University of Alaska - Fairbanks; **UiT**: UiT The Arctic University of Norway; **UNIS**: The University Centre in Svalbard; **UNN**: University Hospital of North Norway; **UoA**: University of Antwerpen; **UoC**: University of California; **UoCa**: University of Calgary; **UoF**: University of Freiburg; **UoG**: University of Gent; **UoGd**: University of **Gdańsk**; **UoGo**: University of Gothenburg; **UoGr**: University of Groningen; **UoH**: University of Hokkaido; **UoIs**: University of Island; **UoL**: University of Leicester; **UoLa**: University of Laval; **UoM**: University of Maine; **UoMu**: University of Murcia; **UoNB**: University of New Brunswick; **UoO**: University of Oslo; **UoOu**: University of Oulu; **UoQ**: University of Queensland; **UoR**: University of Reading; **UoStA**: University of St. Andrews; **UoWa**: University of Waterloo; **UQAR**: Université du Québec à Rimouski; **UT**: University of Texas; **UTu**: University of Turku; **VU**: Vrije University Amsterdam; **WHOI**: Woods Hole Oceanographic Institution; **WU**: Wageningen University

Recent doctorates

Yonas Zewdu Ayele

Risk-based analysis of drilling waste handling operations. Bayesian network, cost-effectiveness, and operational conditions

The aim of this research is to evaluate, identify, and propose a methodology for drilling waste handling practices by considering the complex and fast-changing nature of operational conditions in the Arctic. Moreover, the study seeks to foster an integrated interdisciplinary understanding of technical and operational risks associated with drilling wastes and their management by implementing risk-based analysis. Furthermore, the study focusses on developing the concept of a dynamic model for spare parts transportation in arctic conditions. The results show that working in the cold arctic environments can, if not managed properly, have a significant negative effect on the cost elements and the risk of events.

Link to the thesis: http://munin.uit.no/handle/10037/9481

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

11 April 2016

Kathrine Ryvold Bakkemo

Francisella noatunensis ssp. noatunensis in Atlantic cod – intracellular localization, innate immune responses and antibacterial proteins

Francisellosis has caused the cod farming industry major economic losses because no vaccine or treatments are available. Understanding host-pathogen mechanisms is especially important when traditional vaccine strategies using inactivated bacteria are not functional. This thesis studied interactions between the host and the disease-causing pathogen *Francisella noatunensis subspecies noatunensis.* Cod macrophages were used to investigate bacterial invasion, localization in the host cell, survival and replication. Expression of immune and antibacterial genes was measured after infection. Invasion, survival and replication of *F. noatuensis* in a cod cell line of epithelial-like cells (ACL-cells) were also examined. Important findings are that *F. noatunensis* can survive and replicate in both cod macrophages and ACL-cells.

Link to the thesis: http://munin.uit.no/handle/10037/9973

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

Joint supervision with NOFIMA

24 November 2016

Trond Erling Barstad

Seasonal adaptation, phenology and survival in gall-inducing sawflies (Tenthredinidae: Nematinae: Pontania)

The phenological adaptation of herbivorous insects in the Arctic may be particularly prone to the negative impact of the current global climate change. Increasing temporal dissociation with their plant resources and their natural enemies such as parasitoids may be detrimental for their survival. The life history adaptations for gall-inducing sawflies in the Arctic followed the common outline for overwintering insects. Hindcasts of temperature conditions in spring for the last 21 years revealed a highly significant advancement in dates of eclosion (the act of emerging from the pupal case or hatching from the egg), which is evidence of global warming. There were, however, large inter-annual differences in eclosion timing, probably caused by the timing of spring snow melt.

Link to the thesis: http://hdl.handle.net/10037/9911

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

4 November 2016

Thomas Ibsa Beka

Geoelectrical structures beneath Spitsbergen–Svalbard derived from magnetotelluric imaging

A series of geophysical surveys were carried out on the geologically important and remote Svalbard using magnetotelluric (MT) imaging. The purpose was to better constrain the geology particularly defining geothermal resources. MT relys on natural source time-varying electric and magnetic field data measured at the earth's surface. We acquired broadband MT data at 80 stations in central and northwest Spitsbergen. From the data, we derived 2D and 3D resistivity models and usd them to characterise the near-surface geology, permafrost structure and a CO_2 storage target reservoir in central Spitsbergen. Our MT models helped to characterise the geothermal potential and crustal architecture in the central and Brøgger peninsula areas of the Svalbard archipelago. The thesis has contributed a new kind of data set to previous studies that relied on surficial, seismic and gravity data from the region.

Link to the thesis: http://hdl.handle.net/10037/9509

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

27 May 2016

Shripathi Bhat

Speciation reversal in sympatric eco-morphs of European whitefish (*Coregonus lavaretus L.*) – phenotypic and genomic consequences

The introduction of non-native species may destabilise ecological barriers to gene flow between native populations. In the 1960s a salmonid fish, vendace, was introduced to the upper parts of Pasvik watercourse and invaded the lakes studied in this thesis. These lakes harbour a post-glacially, sympatrically diverged eco-morph pair of European whitefish, namely DR and LSR. The vendace, a planktivore that competes successfully with the DR, relegated this eco-morph from its native pelagic habitat into the non-native littoral habitat, which is mainly occupied by the LSR. This thesis studied the phenotypic, genetic, and genomic consequences of the vendace invasion on native sympatric European whitefish eco-morphs. The studies documented that invasion of vendace has induced speciation reversal in the eco-morph pair.

Link to the thesis: http://hdl.handle.net/10037/9670

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

20 September 2016

Marie-Anne Ermeline Blanchet

At-sea behaviour of the world's northernmost harbour seal (*Phoca vitulina*) population in a changing Arctic

The thesis explores movement patterns and foraging behaviour, and the ontogeny of these behaviours, in harbour seals from Svalbard. The seals showed a strong preference for the west side of the archipelago, where they stayed within 50 km of the coast on the shelf, seldom entering the fjord systems especially in the winter. During upwelling events, the West Spitsbergen Shelf is flooded by Atlantic Water masses, which were specifically targeted by the seals. Presumably these water masses brought Atlantic fish species close to shore. This study strongly suggests that the West Spitsbergen Current west of Svalbard is a determining factor for the presence of this harbour seal population in the High Arctic. The predicted warming will likely favour an increased abundance and a broader distribution of harbour seals through a borealization of the marine ecosystem along the coast of the Svalbard archipelago.

Link to the thesis: http://hdl.handle.net/10037/9138

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

15 April 2016

Chia Jung Chang

Atlantic salmon type I interferons: Protection against virus infection *in vivo* and function as adjuvants in a virus DNA vaccine

Norway is by far the country that produces most salmon in the world, and virus disease is one of the main causes of economic loss in fish farming. To combat diseases, vaccines have been developed. In Norway, traditional vaccines based on inactivated virus are available against some viral diseases, but do not appear to give adequate protection. Chang and colleagues have shown that salmon type I interferon (IFN-I) induces a strong antiviral activity and protection against infectious salmon anemia virus (ISAV) and salmonid alphavirus 3. They also studied IFN-I as adjuvants in fish DNA vaccines. They chose ISAV haemagglutinin esterase DNA vaccine as the model and co-injected it with salmon IFN-I plasmid. The results show a strong adjuvant effect of salmon IFN-I, and demonstrate for the first time that IFN-I could be useful for development of vaccines to be used in fish.

Link to the thesis: http://hdl.handle.net/10037/9513

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

25 August 2016

Mona Maria Fuhrmann

The role of the invasive red king crab in the food web of a high-latitude fjord. Studying macrobenthic communities and trophic control in Porsangerfjord, northern Norway

The thesis examined how predation by the red king crab may affect the benthic community, productivity and the food web in Porsangerfjord. The red king crab is a generalist, opportunistic predator, feeding on multiple trophic levels. Small and large crabs are likely to affect different habitats and prey species, but took a similar trophic position in the food web. Medium-sized and large crabs played an important role in the food web through top-down effects on large, long-lived benthic invertebrates, but had little significance as prey for higher trophic levels and affected mainly the benthic compartment of the food web. In the future, king crabs may partly replace these invertebrates as major predator in the benthos. Predation pressure by the red king crab may be buffered by high production in some prey, but may lead benthic communities to a system with overall lower biomass and higher turnover, with unknown consequences for ecosystem stability and resilience.

Link to the thesis: http://hdl.handle.net/10037/9974

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

24 November 2016

Samuel Jakob Geiseler

Breathtaking brains – Intrinsic neural adaptations to hypoxia

Despite the brain's high vulnerability to hypoxia (insufficient oxygen supply), a number of animals are exposed to and survive it on a regular basis. This project investigated the intrinsic adaptations to hypoxia such animals must consequently possess. Geiseler et al. demonstrate potassium-dependent ATP channels in the eider duck brain, which may help reduce neuronal activity during hypoxia to reduce energy demand. In the hooded seal, neuronal activity is maintained during hypoxia, both in the presence of glucose and during aglycemia, possibly due to high neural glycogen reserves. For the first time, Geiseler et al. recorded synaptic activity in the hippocampus of large mammals. In the hooded seal, such activity is maintained in severe hypoxia for >3h, possibly due to an alternate pre-synaptic calcium regulation.

Link to the thesis: http://hdl.handle.net/10037/9426

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

7 April 2016

Thomas Gölles

Impurities of glacier ice: accumulation, transport and albedo

The Greenland ice sheet has seen accelerating mass loss in recent decades. Parts of the ice sheet are darkening by about 2% per decade and this leads to more melt and rising sea levels. Darkening is caused by natural and man-made particles, the darkest of which result from incomplete burning and are called "black carbon" (BC). Being small and light, they can be blown thousands of kilometres, and a very small amount is sufficient to darken snow or ice. The effect of BC on snow lasts only until the next snowfall; the effect on ice can last for decades. In this thesis, Gölles developed tools to study the interplay of particle accumulation, ice flow and ice melt. Melt-out of particles depends on air temperature; thus the darkening effect is stronger under warmer conditions. The study estimates that if the climate is 8°C warmer in 2300, the darkening effect of BC would increase mass loss from the Greenland ice sheet by 7% through the year 3000.

Norwegian University of Life Sciences
Department of Mathematical Sciences and Technology

Joint supervision with Department of Arctic Geophysics
University Centre in Svalbard

29 September 2016

Silje Eriksen Holmen

Trends and variability of polar mesopause region temperatures attributed to atmospheric dynamics and solar activity

The mesopause is a part of the atmosphere located between 80 km and 100 km above the ground. At these altitudes, it is difficult to measure temperature directly. Therefore, we measure other parameters, which we know are related to temperature, and calculate temperature from these. One phenomenon we can utilise to calculate temperature is airglow. In this thesis, we investigated seasonal variations and trends in temperatures in the mesopause over two arctic locations: Tromsø (70°N, 19°E) and Longyearbyen (78°N, 16°E). Temperature over Tromsø varies with periodic oscillations that may be explained by atmospheric wind patterns and waves generated near the ground. Temperature over Longyearbyen shows a slightly different variation, indicating that local factors play a role. The winter trend over Longyearbyen is near zero from 1983 to 2013, while the trends over Tromsø from 2003 to 2014 are negative in winter and near zero in summer.

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

Joint supervision with Department of Arctic Geophysics
University Centre in Svalbard

19 December 2016

Solveig Joks

"Laksen trenger ro." Tilnærming til tradisjonelle kunnskaper gjennom praksiser, begreper og fortellinger fra Sirbmá-området
["The salmon needs tranquillity." Approaching traditional knowledge through practices, conceptions and stories from the Sirbmá area]

This thesis makes visible the continuity in practices and communities of practice. The Deatnu river comes into being and takes its shape through practices, observations and stories. Traditional knowledge is clearly visible in the practices of salmon fishing. The knowledge is expressed in the observations that people make while being on the Deatnu river, and through the relations that they have to the salmon. Different kinds of relations are established through different fishing methods. The Deatnu river is therefore experienced differently by different actors. Traditional knowledge practices are different from the management practices, which are mostly based on scientific knowledge. If traditional knowledge is to be incorporated into official management, the differences between knowledge practices have to be recognised. Those differences require space for expression. Traditional knowledge will only become available to management if this can be achieved.

Link to the thesis: http://hdl.handle.net/10037/9668

UiT The Arctic University of Norway
Faculty of Humanities, Social Sciences and Education
Department of Sociology, Political Science and Community Planning

14 September 2016

Susanne Kortsch

Marine food-web structure and community patterns in high-latitude marine ecosystems

A main aim of this PhD project has been to study how community and food-web structure changes along environmental and climatic gradients, and to elucidate how species respond to climate warming in the Arctic. Network analysis has been used to study how the network of who eats whom in the Barents Sea changes from the boreal, warm-water regions in the southwest to the cold-water, arctic regions in the northeast. The researchers documented differences in the food-web structure across the entire Barents Sea, separating biogeographic food-web regions. They also showed that the current climate-driven poleward shift of boreal fish in the Barents Sea affects the arctic food web by increasing its connectivity and decreasing its modularity. Along the rocky shores of Svalbard, they documented a regime shift in the sea-floor communities most likely as a response to warming.

Link to the thesis: http://hdl.handle.net/10037/9639

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

24 June 2016

Susan Mariah Lindecrantz

Waveguide Mach-Zehnder interferometer for measurement of methane dissolved in water

This dissertation describes the development of a highly sensitive and compact optical methane sensor, and the study of its optical properties. Because methane is such a critical greenhouse gas, it is important to monitor methane emissions from both human activities and natural sources, e.g. from the seas and permafrost regions in the arctic. This integrated optical sensor consists of optical waveguides forming an interferometric structure. The top surface of the sensor is covered with a highly sensitive layer, consisting of a polymer mixed with a supramolecular compound that captures methane molecules. When the methane molecules are trapped, the refractive index of the sensitive layer changes and this is detected by the interferometric waveguide structure. Laboratory testing showed that the sensor measures methane with high sensitivity in both air and water.

Link to the thesis: http://hdl.handle.net/10037/9236

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

25 April 2016

Miriam Marquart

Marine microbial eukaryotes in Svalbard waters: Seasonality, community composition and diversity

There is an increasing awareness of the importance and diversity of the microbial eukaryotes in arctic regions, but their role in the ecosystem is still largely unknown. Sampling was conducted in Svalbard waters with focus on a time series station in Adventfjorden during 2011-2012. The results revealed a strong seasonal-influenced succession of microbial eukaryote with a diverse and active community even during the polar night. Molecular tools not only revealed new taxa contributing to the vertical export, but also suggested new potential mechanisms for vertical export demonstrated by parasite-host interactions. This study emphasises the extreme seasonality of arctic microbial eukaryotic communities driven by the environment (e.g. light regime) but point to the necessity of thorough knowledge of hydrography for full understanding of the communities' succession and fate.

Link to the thesis: http://hdl.handle.net/10037/9804

UiT The Arctic University of Norway
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Joint supervision with the Department of Arctic Biology University Centre in Svalbard

18 October 2016

Hanne Kirsti Mæhre

Seaweed proteins – how to get to them? Effects of processing on nutritional value, bioaccessibility and extractability

As a consequence of the expected population growth towards 2050, the demand for food proteins will increase. Utilisation of marine raw materials for food and feed is currently low and should be increased. This project aimed to examine the nutritional quality of seaweed proteins, along with the effects of processing on bioaccessibility and extractability, and to evaluate their suitability as food, feed or ingredients thereof. Biochemical analyses showed that most seaweeds are low in lipids and high in minerals. Several seaweed species were rich in good quality proteins, able to cover human requirements for essential amino acids. The project concludes that some seaweed species are good sources of high quality proteins and that processing seems to increase the utilisation potential. However, as only *in vitro* models were used, the results must be confirmed in pre-clinical and clinical models.

Link to the thesis: http://hdl.handle.net/10037/9130

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

11 March 2016

Ngoc Duy Nguyen

The economics of open-access fisheries: Subsidies and performance of Vietnamese fisheries

This dissertation analyzes the economics of an open-access fishery and evaluates the effects of government subsidy programmes on the fishing industry. Results indicate that the Government's subsidy interventions have had a negative impact on the sustainable development of the offshore fisheries. The thesis states that it would be wise for Vietnam to seek to operate a fisheries management system that is designed to prevent overfishing and overcapacity, and to promote recovery of overfished stocks for offshore fisheries, hence approaching the goals of sustainable development. Finally, the dissertation contributes to development of methods for comparing the economic performance and efficiency of vessels by standardising fishing effort and constructing a Salter diagram. The dissertation contributes to the literature regarding evaluation of the treatment effect of a subsidy programme on a Southeast Asian fishery.

Link to the thesis: http://hdl.handle.net/10037/9416

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

10 March 2016

Alice Marie Pedersen

Calanus® Oil. Utilization, composition and digestion

This thesis investigated if the use of commercial proteolytic enzymes could improve oil recovery from *C. finmarchicus* in an industrial-like process, and characterised the oil obtained. The results showed a substantially higher oil yield with the use of proteolytic enzymes compared to standard fish oil production technology. The main components of the oil extracted from *C. finmarchicus* are monoesters of long-chain fatty acids and fatty alcohols, namely wax esters. In addition, the oil is rich in the deep red antioxidant astaxanthin, present mostly as di- and monoesters. Studies on the digestion of wax esters in mice fed a high fat diet supplemented with 2% Calanus® Oil confirmed that the mice were able to digest and absorb the Calanus® Oil. Feeding mice a high fat diet supplemented with a small amount of wax ester-oil attenuated their body weight gain, in line with recent published studies.

Link to the thesis: http://hdl.handle.net/10037/9759

UiT The Arctic University of Norway
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The Norwegian College of Fishery Science

3 July 2016

Vitaly Alexandrovich Postoev

Using medical birth registries in the Kola Peninsula for birth defects surveillance and investigation of their risk factors.

In northwest Russia, medical birth registries were initiated in 1997 in the city of Monchegorsk and extended to all of Murmansk County in 2005. This thesis demonstrates the effectiveness of these data sources for surveillance of birth defects with the following objectives: (i) estimate changes in prevalence of birth defects during a 40-year period, (ii) identify effect of ultrasound screening during pregnancy, (iii) define factors associated with urinary malformations. The study, with data from 1973 to 2011, showed that the prevalence of birth defects doubled, and the initiation of prenatal ultrasound screening was the most likely reason for such changes. The screening was also the main reason for the decline in perinatal mortality among newborns with birth defects, primarily due to prenatal detection of severe malformations with subsequent terminations of such pregnancies.

Link to the thesis: http://hdl.handle.net/10037/10013

UiT The Arctic University of Norway
Faculty of Health Sciences

18 November 2016

Dilli Prasad Rijal

Invasive *Heracleum* in northern Europe: Introduction history and impact on native plant diversity

Exotic invasive giant hogweeds are infamous in Europe for the ecological and economic damage they cause, but their impact on plant diversity has not yet been fully explored. In addition, uncertainties in their source and route of introduction impede management interventions. This thesis developed a microsatellite library for hogweeds, reconstructed the introduction history and evaluated the impact of *H. persicum* on Norwegian plant diversity. The microsatellite markers clearly discriminated the genetic structure of hogweeds and their hybrids. In contrast to the contemporary hypothesis of an English origin of Norwegian populations, Finland appeared as a more likely source. *H. persicum* cover had a strong negative effect on native cover, and species richness was reduced in the invaded plots. This justifies urgent management interventions to control and eradicate it.

Link to the thesis: http://hdl.handle.net/10037/9114

UiT The Arctic University of Norway
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Department of Arctic and Marine Biology

15 January 2016

Atal Saha

Genetic complexity in the marine environment: Population genomics of saithe (*Pollachius virens*), Greenland halibut (*Reinhardtius hippoglossoides*), beaked and golden redfish (*Sebastes mentella* and *S. norvegicus*) in the North Atlantic

This thesis investigated the genetic complexity in four commercially exploited species from the North Atlantic: saithe, Greenland halibut, and beaked and golden redfish. Biologically distinct populations were found within each of these species. The results indicate a correlation between genetic differentiation and differences in life history of the species, and imply that distinct genetic heterogeneity can exist in different marine species and may be influenced by abiotic and biotic factors. The new definition of gene pools may serve to define biologically meaningful management units to ensure their sustainable exploitation and preserve evolutionary legacies. This study is the first to use single-nucleotide polymorphism to investigate the genomes of saithe, Greenland halibut and beaked redfish populations.

Link to the thesis: http://hdl.handle.net/10037/9482

UiT The Arctic University of Norway
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Department of Arctic and Marine Biology

Joint supervision with the Institute of Marine Research

4 May 2016

Simone Sauer

Past and present natural methane seepage on the northern Norwegian continental shelf

This thesis attempts to understand past and present methane cycling on the northern Norwegian margin. A comparison of the carbon cycling in the surface sediments of a cold seep site on the Vesterålen shelf and organic-rich sediments of a northern Norwegian fjord revealed distinctly different organic carbon sources, accumulation rates and turnover processes. The study of methane-derived authigenic carbonates (MDACs) from the seep site on the Vesterålen shelf provided insight into formation environment and source fluids, most importantly, information on the temporal constraints of methane seepage, inferred from U-Th dating. Current knowledge indicates that methane seepage in the Hola trough started at least 11 000 years ago, probably even slightly before. The strongest events of past methane seepage and carbonate formation likely occurred around 10 000, 4 000 and 2 000 years ago.

Link to the thesis: http://hdl.handle.net/10037/9548

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

30 June 2016

Runar Gjerp Solstad

Antimicrobial peptides in *Urticina eques* and *Echinus esculentus*. Isolation, characterisation, and structure–activity relationship studies

Bacterial resistance to antibiotics has become a serious global problem. New antibacterial drugs are desparately needed. Antimicrobial peptides (AMPs) are a diverse group of compounds often capable of killing both bacteria and other microorganisms. AMPs have been suggested as an option for treating bacterial infections where traditional antibiotics have little effect. The overall aim of the study was to discover and characterise novel AMPs in Echinodermata and Cnidaria. The most potent AMPs were discovered via bioassay-guided purification in the edible sea urchin *Echinus esculentus*, killing bacteria at low micromolar concentrations and fungi at somewhat higher concentrations. This AMP was antibacterial exclusively towards the Gram-positive *Corynebacterium glutamicum* at 50 µM. Furthermore, analgesic activity was demonstrated *in vivo* in rats.

UiT The Arctic University of Norway
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The Norwegian College of Fishery Science

9 December 201

Eike Ingrid Stübner

What are the forces that form seasonality in the marine organisms?

This thesis aimed to increase our knowledge on meroplankton dynamics and their ecological role in the arctic marine coastal ecosystem. Three different approaches were applied to investigate the highly dynamic nature of meroplankton and how they relate to biological and environmental drivers, and their potential feeding impact during mass occurrences. Meroplankton contributed considerably to the total zooplankton abundance during the productive season. A strong correlation of total meroplankton abundance with phytoplankton biomass was observed as a general pattern. The timing of the spring bloom determined the onset of the "meroplankton-boost". The occurrence of different bivalve larval species was strongly seasonal. The investigation suggests that benthic invertebrate larvae play a significant role in arctic coastal pelagic ecosystems, linking the pelagic and benthic realms.

Link to the thesis: http://hdl.handle.net/10037/10018

UiT The Arctic University of Norway
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Department of Arctic and Marine Biology

Joint supervision with the Department of Arctic Biology University Centre in Svalbard

14 December 2016

Bente Sundsvold

«Den nordlandske fuglepleie» – Herligheter, utvær og celeber verdensarv. Mellom tekster og praksiser i Vegaøyan

["Bird-tending in Nordland" – Amenities, outskirts and world heritage. Between words and deeds in the Vega archipelago]

In 2004, the Vega archipelago was inscribed as a UNESCO World Heritage Site, based on the now unique practice of eider down harvesting. The thesis follows the process of WH inscription, and the practice of eider down harvesting as it is performed today. It explores the powerful transformations the practice has undergone during the past century, from valuable amenity to marginalisation, to entering the prestigious World Heritage list. "Den nordlandske fuglepleie" refers to a particular form of co-domestication, arguing that in this practice the birds domesticate the humans as much as the humans domesticate the eiders. Video cameras expand the field of observation, allowing the researcher to explore both humans and birds as subjects in the interaction, although they share neither language nor perceptive faculty.

Link to the thesis: http://hdl.handle.net/10037/8457

UiT The Arctic University of Norway
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22 February 2016

Ilona Urbanova

Sea anemone transcriptomes and their responses to climate change stressors

Little is known about sea anemones at the cellular and genetic level. They appear to be a biological model system well suited to research on fundamental processes in biology and ecology, and to medical research on cancer and other disease genes. The researchers developed a fast, efficient, large-scale method (Digital Marine Bioprospecting), to find multiple biomolecules with potential for commercial exploitation. They also studied a sea anemone (*Anemonia viridis*) to identify the effects of climate change on marine organisms, specifically studying how this species reacts to ocean acidification. A high level of stress at low pH conditions was demonstrated. Sea anemones have proven to be informative model organisms in climate studies, and there is every reason to believe that such studies are representative of animals in general, and probably also for humans.

UiT The Arctic University of Norway
Faculty of Health Sciences
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2 December 2016

Birthe Vang

Recovery and properties of oil from the copepod *Calanus finmarchicus*

The zooplankton *Calanus finmarchicus* is present in large amounts in the North Atlantic and has lipid-rich stages, which can be harvested. This study demonstrated that methods involving use of proteolytic enzymes gave substantially higher oil recovery from *C. finmarchicus* than standard fish oil production methods. The oil obtained from *C. finmarchicus* was rich in the powerful antioxidant astaxanthin and **ω**-3 fatty acids, found mainly as wax esters. Tropomyosin is known to be the main allergen in crustaceans and another objective was to investigate if this protein could be detected in Krill and Calanus oils. Tropomyosin was not detected in Calanus oil probably due the production method. A method for accurate determination of the protein content in oils by direct amino acid analysis was also developed.

Link to the thesis: http://hdl.handle.net/10037/8426

UiT The Arctic University of Norway
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29 January 2016

Hanne Maaret Vidgren

Remediation of contaminated marine sediments – Sediment capping technology and adverse effects of remediation actions

Contaminated marine sediments and suspended sediment pose ecological and human health risks, and less invasive sediment management approaches are needed. Studies carried out in three sites on the Norwegian coast specifically address (i) the technical challenges and adverse effects of thin sand cap construction, (ii) initial cap efficiency during consolidation of the underlying sediments, (iii) dredging-induced plumes as a model input, and (iv) monitoring of the suspended sediment plumes arising from the operations. The results show the importance of an appropriate cap design to minimise the effects of consolidation-induced advective transport. Sediment characteristics were found to affect the dredge plume source terms and complicate the far-field model input. An acoustic method was advantageous for understanding the suspended sediment plume induced by capping.

UiT The Arctic University of Norway
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4 February 2016

Gísli Arnór Víkingsson

Decadal changes in distribution, abundance and feeding ecology of baleen whales in Icelandic and adjacent waters. A consequence of climate change?

During the last two decades, the marine physical and biological environment around Iceland has changed substantially. Increased sea temperatures have apparently caused a northward shift of several fish species, a reduced abundance of krill, and a near collapse of the sand-eel population. Simultaneously, appreciable changes were detected in whale populations in the area, including a northward shift of blue whales, a rapid increase in humpback whale abundance, a steady increase in abundance of fin whales in the Irminger Sea and an abrupt decrease in abundance of common minke whales in Icelandic near-shore areas. These changes in whale distributions and abundance are most likely associated with changed availability of some important prey species. The results indicate that climate change has already started to have effect on the distribution of cetaceans in this region.

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15 January 2016

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