FRAM CENTRE

FRAM FORUM 2016

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Editor
Janet Holmén
Freelance editor
// alchemia@online.no

Project leader
Helge M. Markusson
Outreach Coordinator
Fram Centre
// helge.markusson@framsenteret.no

Editorial committee

Michaela Aschan
UiT The Arctic University of Norway
// michaela.aschan@uit.no

Eva Therese Jenssen
University Centre in Svalbard
// eva.therese.jenssen@unis.no

Christine F. Solbakken
NILU – Norwegian Institute for Air Research
// christine.solbakken@nilu.no

Randi M. Solhaug
UiT The Arctic University of Norway
// randi.solhaug@uit.no

Gunnar Sætra
Institute of Marine Research
// gunnar.saetra@imr.no

Cover photo
Audun Rikardsen

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TANK Design AS
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Contact information
FRAM Forum
Fram Centre
POB 6606 Langnes, N-9296 Tromsø
NORWAY

www.framsenteret.no
post@framsenteret.no
Phone: +47-7775 0200

A SEA CHANGE IN THE HIGH NORTH

"Norway is in transition", said Vidar Helgesen.

The Norwegian Minister of Climate and Environment was in Tromsø in January for the Arctic Frontiers conference - and for another auspicious occasion that we will get back to later. The transition he is referring to is a socioeconomic one. For decades, Norway has enjoyed prosperity based on a rich natural resource under the sea: petroleum. But with oil prices falling, the Norwegian economy has slowed down. Can the country increase its income from other sources?

At the same time, we observe signs of environmental change in the northern seas. The ice cover is shrinking. Fish populations are on the move. Even the seawater is not quite the same as it has been. These changes also necessitate a transition - not least away from fossil fuels. But do the changes pose a threat to Norway's economy, or offer unique opportunities?

Let us turn to Arctic Frontiers, an annual event where policymakers, business leaders and scientists meet in Tromsø to discuss sustainable development in the Arctic. This year's conference had a strong focus on the sea, with presentations on challenges and opportunities in the Arctic, energy and food security, protection of infrastructure and environment, innovation, and the "green shift".

Overall, the participants at Arctic Frontiers were clearly looking to the future with optimism, but speaker after speaker emphasised that knowledge would be crucial - research-based knowledge - along with cooperation, partnership, and dialogue.

One of the themes discussed at the conference, food security, is an excellent example of the wide range of disciplines that can have bearing on a single issue. What do you know about the fish on your plate? Is it safe to eat? Does its production place a burden on the ecosystem? Can you count on being able to buy the same kind of fish next time you go shopping? The answers to these questions come from *biologists* and *ecologists* who study the ecosystem that supports the fish; from *oceanographers* who study the dynamics of the sea where the fish live; from *chemists* who study the water the fish live in; from *toxicologists* who study plastics and pollutants in the fish; from *innovators* and *engineers* who develop better ways to catch the fish; from *legal experts* and *environmental managers* who ensure sustainable harvesting of fish. Working together, these experts can make sure the fish on your plate is safe for you to eat, safe for the environment, and not in danger of extinction.

And that is where the Fram Centre comes in.

FRAM - the High North Research Centre for Climate and the Environment, was originally established to foster *interdisciplinary* research. The vision was to gather natural and social sciences, technology and innovation under a single roof, facilitating interactions between experts from different fields and with different perspectives. This generates exactly the type of broad, research-based knowledge so eagerly requested by the delegates at Arctic Frontiers. And this is what the Fram Centre has been doing for years. But there was a problem: with all this activity, the Fram Centre was bursting at the seams.

Which brings us back to the other auspicious occasion that brought Vidar Helgesen to Tromsø: the groundbreaking ceremony for Fram Centre Phase II, the long-awaited expansion that will nearly double the Centre's floor space and allow more of its research institutions to gather under the same roof. When the new building is completed, the Tromsø branch of the Institute of Marine Research will join the institutions already housed in the Fram Centre. This will make it even easier to bring together the competence required to create new research-based knowledge that will guide Norway into the changing future.

Norway is in transition and the High North is going through a sea change. Although it is not clear what the future will bring, the go-ahead for an ambitious construction project at the Fram Centre signals a solid government commitment to knowledge. This is not just a recognition of the work the Centre has already done, but also a strong signal of what it is expected to achieve in the future. With the groundbreaking for Phase II, the Fram Centre is also changing, yet it stands firm as a rock.

Janet Holmén, Editor

Picture of the year

After spending five weeks aboard the Research Vessel *Lance* with the N-ICE project, my colleague Andy Isaacsson and I were returning to Longyearbyen. The helicopter pilot offered to circle the ship and open the doors so I could shoot some photographs. I sat on the edge of the helicopter with the wind pushing my camera into my face and my eyes full of water. I was able to get just a few frames before the mist encircled the ship and obscured it from view. The picture shows *Lance* "moored" to the edge of an ice floe, with ropes running from the ship to stakes in the ice. If you look very carefully, you may spot a member of the science team, Jean-Charles Gallet, working on the ice a few hundred metres away from the vessel. He's in a "snow pit" taking samples for detailed analysis of snow crystals as part of his work on the snow cover of sea ice.

Text and photo: Nick Cobbing

Ole Magnus Rapp

The man with the golden Canon

Audun Rikardsen gets the gold in both scientific research and photography. This smiling, imaginative professor of fish biology isn't quite like the rest of his colleagues at UiT The Arctic University of Norway, an institution he himself might prefer to describe as "Midnight Fun University".

Photo: Ole Magnus Rapp

PATIENCE IS ONE OF HIS STRENGTHS and has enabled him to forge something akin to friendships with both walruses and humpback whales, and has also allowed him to produce well-planned photographic images that have strengthened his outreach capabilities and won him major awards.

And he carves out new paths: after many years' intense research he and colleagues discovered where wild salmon actually migrate. These findings were an international sensation, which the researcher chose to publish first in a book for children.

Patience is a quality he also appreciates in his friends and relations when he is out on a photographic assignment. He sometimes uses them as actors in his photographs, such as the man jumping on skis over a small fishing boat and landing in the sea. When the photographer wants the stunt repeated over and over again until the image is perfect, patience is a great thing to have – for the model, too.

His partner Tine Marie knows that when Audun sees beautiful light conditions around the island of Kvaløya and the whales are leaping, he'll be heading out, usually in a rigid inflatable boat. It's difficult to say when he'll return, but he almost invariably brings home a good "catch" in the form of exciting research or some fine pictures.

IMPORTANT SUPPORT

He first met Tine Marie Hagelin, his partner, prop and mainstay, through his combined passion for scientific research and photography. When Rickardsen was in Greenland marking salmon, he took the photo that made him Nordic Wildlife Photographer of the Year for the first time in 2012. The prize included a stay in a barren landscape near the Finnish-Russian border to photograph wolves and bears. It was there he met Tine, who at the time was working for WWF Norway, but who eventually moved to Tromsø and now heads the Council for Arctic Coast Outdoor Pursuits. She shares Audun's interest in nature and fresh air, and he gives her a lot of credit as his inspiration.

Professor Rikardsen combines cutting edge expertise as a fish biologist with a keen interest in outreach activities. Not only that, his photographic talents have swiftly earned him a place among the ranks of elite wildlife photographers. His unique photographs of fish, seals, eagles and whales have attracted attention the world over, and some of his images are on display in the reception at the Fram Centre.

SATELLITE TRANSMITTER

Arctic char once swam outside Norway's most beautiful university building, the Norwegian College of Fishery Science. But the College had no licence to do research on them, even though the foremost expertise in the field was sitting inside its four walls. Now there is a thin sheet of ice on the water that flows beneath the decorative pier at the entrance, and Audun Rikardsen receives us with a broad smile.

"Both crucian carp and arctic char used to swim here, but now there are only sticklebacks left", says this professor, photographer, disseminator and bighearted friend of aquatic animals and fish.

Rikardsen smiles a lot; unflappable amongst people, he is happiest in a fleece jacket and hiking boots. The coffee cup in his office is shaped like a Canon camera lens. His bookcase is full of specialist literature on fish and whales in English and Norwegian, as well as books on many other subjects ranging from coastal birds and animal biology to acid rain. The shelves also hold various photography thingamajigs, an advanced satellite transmitter for salmon, and a deodorant.

A LUCKY MAN

Rikardsen feels fortunate to be able to work on biology projects he found fascinating even as a boy back home in Steigen, in the days when he would turn over every pebble on the beach hunting for small animals.

Now his research findings on the migration of wild salmon are being published internationally, and he can watch humpbacks and killer whales from the veranda of his home at Skulsfjorden on an almost daily basis. His photographs are used in the media, and he often employs them to spread knowledge, for example about how the migration patterns of herring change over time and how this affects the whales that follow them.

The professor stresses how privileged we are in Tromsø, having things like the world's largest accumulation of whales right on our doorstep during the long polar night. A unique situation for fishermen, the tourist industry, city residents and researchers.

IT'S OUR DUTY TO MAKE KNOWLEDGE AVAILABLE!

The Norwegian broadcasting corporation, NRK, is currently making a documentary about Rikardsen, about how he plans and carries out various photography projects and how he combines them with his research and outreach activities.

Photo: Audun Rikardsen

Unlike many of his colleagues, Rikardsen is not afraid of the media or fellow scientists' perhaps envious comments. That researchers should be visible with their knowledge goes without saying.

"Research has little value if you don't disseminate it to people other than your own colleagues. Academics have a duty to get involved; they must dare to simplify the message from their research without inserting ifs, ands or buts to protect themselves against criticism from colleagues. And dare to have an opinion on things a little outside their own special area of expertise."

PHOTOGRAPHY COURSE FOR RESEARCHERS

Another of Rikardsen's hobby horses is that researchers in general take far too few photos of their work out in the field and in the laboratory. He has given several talks about research photography for his colleagues, and reminded them how important a good image is for disseminating and visualising research results, through lectures and - not least - the media. It is indeed often the image that sells. He offers some simple but important advice:

1. Always carry a camera!

2. Set aside time for photography breaks when planning your project and think in advance about what kinds of images you want.

3. Construct a real-life situation that captures the essence of the research, and get close to and on a level with the photographic subject. Remember to include the researchers' faces, ideally with an expression that shows that they enjoy what they are doing.

LIFE ON THE SEASHORE

The seashore, the sea, the mountains and the wildlife back home in Steigen, along with the influence of his parents - who were both outdoor enthusiasts - determined young Audun's choice of career. He was never in doubt. It had to be something in biology. The hidden life beneath the pebbles on the seashore, the birds in his countless home-made nesting boxes, the trout in the local streams: all these were a constant source of fascination, and with a salmon-fishing father he ended up with freshwater biology as his specialist field.

But with several whaling men in the family and a great passion for all life in the sea, Rikardsen's limnological specialisation didn't prevent him from getting involved in research into marine fish and mammals.

FROM FRY TO WHALE

Most of his research has probed salmon migration in rivers and oceans. But the principles and the theories about why and how animals migrate are often the same, even if those animals differ in size, from tiny salmon fry swimming in the river to the gigantic whales that gather in the sea off Tromsø in the long polar night. The methods used to map the animals' migration are also often the same.

LATEST NEWS ABOUT SALMON

Rikardsen's research on anadromous fish and on where salmon migrate in the great oceans when they leave their home rivers has cast new light on a species that is considered one of the world's most intensively studied.

"Look here", he says. "Most of the salmon from Norwegian and European rivers go north. We find them near Svalbard as far as 80 degrees north and all the way east to Novaja Zemlya. This is largely contrary to previous knowledge and the belief that salmon mainly stayed in the southern waters of the North Atlantic, scarcely at all in the Barents Sea." He points enthusiastically at a map plotting the salmon's migration route from the Alta River. He made the map himself, but gives modern satellite-based electronic tracking technology the credit for making it possible to chart these migration routes. Rikardsen admits to an almost nerdy interest in developing the technology - including electronic tracking equipment, photographic accessories and home-made gadgets. Anything to make a device simpler to use but better adapted for its purpose than its off-the-shelf counterpart.

NOVICE PHOTOGRAPHER

Even though Rikardsen took quite a few photos in his teens, this great passion for photography is quite new. Inspired by a

season of field work on the island of Bjørnøya in the summer of 2009, he bought his first digital single-lens reflex camera. Since then, his interest has simply grown and grown.

He likes trying to take "impossible photos", and the ones he wins prizes for in major international photography competitions are often those that demanded a great deal of planning, creativity, knowledge and, not least, time. Not to mention countless disappointments and a great many expletives. But they are counterbalanced by fantastic wildlife experiences and triumphs on the road to his stunning images.
Rikardsen is often fascinated by the interaction between animals and humans along the coast, and by the thin surface that both separates and connects two completely different worlds above and below water.

SELF-DEVELOPED TECHNOLOGY

During the past year he has given a lot of thought to how it might be possible to capture - in a single photograph - the image of a killer whale under water, and a world of fishing boats and seabirds above water. Existing photographic equipment can capture such images in good light, but the dim light of the long dark winter when the whales gather offshore poses some enormous optical challenges. After much thought and experimenting, Rikardsen designed his own underwater camera case with a graduated grey filter that compensates for the different amounts of light above and below water. Norwegian viewers will be able to see this entire process, and find out whether Rikardsen finally manages to capture his dream image, when the NRK documentary is broadcast this fall.

BRILLIANT IMAGES

He often combines field work with photography, taking well-planned images that are brilliant both technically and subject-wise. With his hectic work schedule, he tries to combine activities, perhaps providing online instruction for students back at the University while sitting on the seashore, observing and photographing walrus visitors to Tromsø. Much-photographed killer whales and humpbacks are also outfitted with electronic tracking equipment in the service of scientific research. At the same time, he takes photos to document the research or as part of the research itself.

Humpback tail fins and killer whale dorsal fins are the animals' own "fingerprints", and Rikardsen's countless photos are used by researchers in Tromsø and around the world to monitor whale populations and migration patterns, supplementing the signals from the electronic transmitters. Whether one is taking photos or marking whales, patience comes in handy.

Photo: Audun Rikardsen

PALS WITH A WALRUS

Rikardsen takes his time, and approaches his photographic and research subjects carefully, to gain their trust.

In the summer of 2014, when a walrus settled down for a while on an island not far from where Rikardsen lives, the photographer visited repeatedly, and the two gradually grew accustomed to one another. Ultimately, a unique friendship developed between a human and an arctic animal that is considered one of the most dangerous creatures one can encounter in the water. The walrus obligingly posed for a variety of shots, some taken at such close quarters that every single whisker is visible.

LOCAL SUBJECTS

Rikardsen finds most of his subjects in his local environment around Tromsø or his childhood home in Steigen: heart-shaped Northern Lights above Sørfugløy, a sea eagle diving for fish, a daring ski-jumper captured with flash over Tromsø in evening light, a reluctant halibut being pulled out of the water on a fisherman's line. For Audun Rikardsen, a single sentence sums it up.

"A good image is like good research: it takes a lot of patience, planning and creativity."

Helge M. Markusson // Fram Centre

Goose patrol

He came to Vesterålen to work with data encryption at an air base. Now Johnny Bakken dedicates most of his life to two things: directing choirs and counting geese. In Vesterålen there are plenty of both.

Johnny Bakken, goose patrol.
Photo: Helge Markusson, Fram Centre

Barnacle geese "refuelling" in Vesterålen. Each year they migrate from Scotland to Svalbard and back, stopping along the Norwegian coast to feed.

Photo: Johnny Bakken

We're a couple dozen kilometres outside the town of Sortland in the Vesterålen archipelago on a clear autumn day. The sheer-sided mountains, clad in the year's first carpet of winter snow, encircle the beautiful green ribbon of pastoral landscape between the mountains and the sea. Even though we are at 68 degrees north latitude, this is one of Norway's most important agricultural areas. Spring comes earlier here than in many other parts of the region. Indirectly, the green grass shoots are the reason why Johnny Bakken, every spring and autumn, spends up to 14 hours a day in and out of his car. He sits patiently, usually at night, equipped with a thermos of coffee and a pair of binoculars, waiting for the geese to arrive. Because in the eyes of the pink-footed goose, the barnacle goose and the greylag goose, Vesterålen is a gigantic "fuelling station".

"It's not unusual for me to log seven or eight thousand kilometres on the road. That's what it takes to keep an overview", explains Johnny Bakken.

In his day job, Bakken is the professional conductor of no fewer than four choirs, but when spring and autumn come, he dons a jacket bearing the logo of the Norwegian Institute for Nature Research (NINA). And then he does his other job: counting the geese that land in the area to fatten up before continuing their migration north or south. He became interested in the geese in the 1990s, when he was working with data encryption at Andøya airbase. Andøya is the base for the Orion surveillance aircraft that make daily flights over the vast expanses of the Barents Sea to monitor maritime and air traffic, including traffic from our neighbour, Russia. Once their mission in the north is accomplished, the planes land and refuel.

Geese also refuel at Andøya. Bakken was fascinated to learn that after feeding in the spring, the geese fly all the way north to Svalbard and that they stop over again in the fall, repeating the process to fuel their return south.

Twenty years on, Bakken is still fascinated by that story and by all the geese.

"People who are used to working in the field are an invaluable asset", says Geir Systad, bird researcher at NINA. "Training field personnel takes time, and it's really best to get them started before they become adults. In that way field work resembles gymnastics. Many youngsters leave as soon as we've trained them, and start doing completely different things."

"But", he adds, "those who are able to work for us year after year know the methods, and can see nuances and opportunities that people less familiar with the work cannot. They often do the job better than we can. I'm hugely appreciative of experienced field workers", explains Systad, who among other things works with behavioural and population ecology with a focus on seabirds.

In the space of just 24 hours, more than 30 000 geese can land in Vesterålen. And Bakken sits there waiting for them, armed with binoculars, camera and click counter.

"I can typically count 1 500 barnacle geese in 24 hours, and I never cease to be fascinated by these birds. To take an example, a bird I had logged where we are now, at Vik, was 'read' up in Svalbard 16 hours later. They have a cruising speed of between 70 and 80 kilometres an hour", says Bakken.

When Johnny Bakken drives around in the spring nights or autumn days counting geese, it is of interest to more people than just himself and the institution that receives the reports.

"The geese that turn up every spring on our green pastures - to me they are living jewels in the landscape. They make the world a more beautiful place."

For the farmers who make their living off the land, the geese are a welcome sign that spring has now arrived, but they can be an ominous signal, too. In the sub-arctic landscape of Vesterålen, it takes little more than a few visits from the geese before the farmer's harvest is severely affected. These are pastures and grasslands that produce high-quality lamb and mutton. And so the number of geese must be kept at a level that ensures their survival while posing no threat to the ecosystem. A *sustainable* level.

It's like a game. The farmers chase the geese; some join forces and build scarecrows to frighten them off, and others shoot at them. And the geese learn.

"The expression, 'silly as a goose' is proved wrong every single year", says Johnny Bakken. "Even after observing them closely over many years, I am still both impressed and surprised by their intelligence, imagination and creativity. I could write a whole book on the subject. Geese have an intricate warning system, in addition to their 'understanding' of whether they are in a safe place or not. Call it instinct if you like, but they can also 'sense' which people pose a threat and which don't."

"Field assistants who know the area well are often invaluable for our projects", says Sveinn Are Hanssen, senior researcher at NINA's department at the Fram Centre in Tromsø. "They are often experienced

Without people like Johnny Bakken, the researchers would have given up. Field workers are helping to ensure that the goose populations in northern Europe are sustainable.

Photo: Johnny Bakken

walkers with unique knowledge of local conditions, who also take more than an average interest in nature. Without their knowledge and skill, it would actually be impossible to carry out certain projects."

Johnny Bakken admits that he really enjoys his sideline.

"Those wonderful Vesterålen nights!" he exclaims. "I see foxes, otters, elk, rough-legged buzzard, golden eagle, peregrine falcon, and then suddenly cranes can land within viewing distance."

But he likes the geese most of all.

"The geese that turn up every spring on our green pastures - to me they are living jewels in the landscape. They make the world a more beautiful place", says Johnny Bakken.

BARNACLE GOOSE IN TEXT AND PICTURES

Ingunn Tombre, senior researcher at the Fram Centre branch of NINA, and author Kirsti Blom have written a book together, about the barnacle goose. In it, they follow the barnacle goose through an entire year, tracing its incredible journey from the wintering grounds in Scotland, north along the Norwegian coast of Helgeland and Vesterålen, to the nesting grounds in Svalbard and back again.

Ingunn Tombre has been studying and working with geese since 1992, and she was quick to realise that they would make good material for a book.

"They are fascinating creatures, with different personalities and a fascinating way of life. A species that is well suited for putting knowledge across." Tombre points out that few fact books are aimed at children and young people. Arts Council Norway has purchased the book, and will distribute copies to schools and public libraries throughout the country. The book is currently available in Norwegian only.

SUCCESS IN MANAGING PINK-FOOTED GEESE

The number of pink-footed geese that nest in Svalbard has grown dramatically in the past decade. Now the population has been reduced to what is considered a sustainable size – and in record time.

As part of an international species management plan, the number of pinked-footed geese was to be cut down through hunting. The aim was to limit the damage grazing geese do to the Svalbard tundra and to reduce conflicts with agriculture on the mainland.

Belgium, the Netherlands, Denmark, and Norway have agreed that the number of pink-footed geese should be about 60 000 individuals. To achieve this, regular autumn hunting has been implemented in Norway and Denmark. The latest count showed 76 000 geese, and Denmark extended the 2014/2015 hunting season to the end of January to increase the number of birds shot. This has had a major impact on the population. The increased hunting in Denmark, along with normal mortality and mortality of birds shot and wounded, has brought the population down to the agreed level.

"We know that if we increase the adult mortality in a long-lived species like the pink-footed goose, this will have an impact on the rising population numbers. Nevertheless, it's a surprise that the hunting has been so effective", says Ingunn M. Tombre, senior researcher at NINA and Norway's expert in the international process.

Read more about this topic on page 16.

With sharp eyes constantly on the lookout for common geese, Johnny Bakken also frequently spots rare geese. Here we see a red-breasted goose (*Branta ruficollis*), classed as Endangered on the IUCN Red List. In the background there are a few barnacle geese, the topic of the book by Ingunn Tombre and Kirsti Blom.
Photo: Johnny Bakken

Pink-footed geese feeding in early spring.
Photo: Ingunn Tombre, Norwegian Institute for Nature Research

Ingunn M. Tombre // NINA – Norwegian Institute for Nature Research
Einar Eythórsson // NIKU – Norwegian Institute for Cultural Heritage Research

Geese beyond borders

We often hear about endangered species. But what about species that are becoming so numerous they endanger their own environment?

PINK-FOOTED GEESE SPEND THE WINTER in northern Europe and breed in the High Arctic. Those that nest in Svalbard pass over Belgium, the Netherlands, Denmark, and Norway, feeding along the way. In recent decades, climate change has improved breeding conditions in Svalbard and the goose population has burgeoned, leading to mounting conflicts with agricultural interests, especially at the spring stopover sites in Norway. In some localities at their breeding grounds, geese have degraded the tundra by grubbing for below-ground plant parts in early spring.

The research project "*Adaptive goose management beyond borders*" focuses on implementing an international management plan for the Svalbard-breeding pink-footed goose. The countries along the goose's flyway have all signed an agreement on objectives and a course of action. In 2012, the plan was approved by the African-Eurasian Waterbird Agreement (AEWA), under the Convention for Migratory Species.

The plan process involved all the relevant stakeholders: farmer's unions, hunting and bird associations, environmental and agricultural managers as well as researchers. But the plan has a top-down structure, and in the *Geese beyond borders* project we try to understand the motivations and expectations of local Norwegian landowners and hunters, and how they will contribute to the plan's overall objectives. Two surveys indicate that many of them are aware of the plan and see themselves as having a role in it.

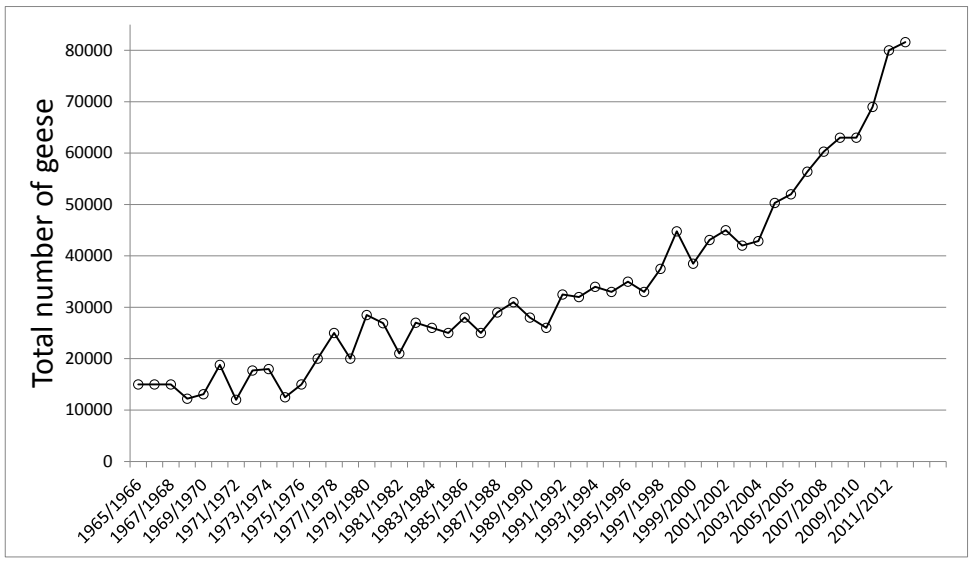
A central aim of the plan is to reduce the goose population, thus reducing conflicts with agriculture and preventing further damage to the arctic tundra. Our previous GOOSEHUNT project demonstrated that improved hunting organisation among landowners could increase harvest rates. Using computer models, we study the effects of various regional management regimes on the harvestable goose population, and the results will be announced to local stakeholders and managers. *Geese beyond borders* also shows how knowledge collected by non-scientists improves local implementation of the management plan. The established governance arenas facilitate communication between environmental and agricultural management and among various stakeholders, and the joint learning process supports the implementation of adaptive management.

FURTHER READING

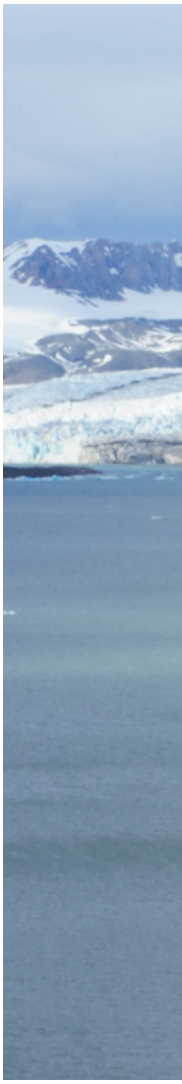
The web page for AEWA International Working Group for the pink-footed goose can be accessed at: http://pinkfootedgoose.aewa.info/

Pink-footed geese feed on agricultural land in Norway during their spring migration to breeding areas in Svalbard.

Photo: Ingunn Tombre, Norwegian Institute for Nature Research



The development of the Svalbard-breeding population of pink-footed goose *Anser brachyrhynchus.*



Zofia Burr and Øystein Varpe // University Centre in Svalbard

Seabird breeding timing at high latitudes

Imagine an Arctic bird cliff in summer, teeming with fledging chicks and predators waiting below. Now fast-forward to a short time later and picture a quiet breeding cliff dusted in snow. What evolutionary adaptations and constraints shape when birds breed in seasonal environments? And when conditions change, will birds breed at the "right" time?

Animals living at high latitudes must adapt to environments where the physical and biological conditions go through extreme changes throughout the year. Phenology, the study of recurring biological phenomena, is one piece of the puzzle needed to understand how animals have evolved strategies to deal with strong seasonality. Seabirds, in addition to being charismatic, are great study subjects because it is far easier to study individual birds than individual fish or plankton, and understanding their breeding timing strategies helps shed light on ecological interactions.

For many species, the timing of when parents reproduce has consequences on the survival of their young. In 1914, Norway's Johan Hjort put forth the idea that fish larvae must have the appropriate prey at the time they hatch in order to survive. This concept has inspired much work on timing across trophic levels. Of course food is an essential part of successful reproduction for birds as well, but factors such as predators, competition with other birds, and the need to finish breeding before summer ends and harsh physical conditions kick in at high latitudes, might also influence when a mother lays her eggs.

At first glance, different seabird species may seem similar to one another, yet they each have specific food sources and behaviours. This leads us to wonder - how do species differ in the strategies they use to time breeding?

We have joined forces with a network of biologists whose work within the SEAPOP programme (www.seapop.no) includes monitoring seabird breeding perfomance at "key sites" along a wide latitudinal gradient in Norway and Svalbard. With support from Fram Centre incentive funding, 12 people representing 7 institutions are working together to understand large-scale variability in seabird breeding timing.

We quantified breeding timing at ten colonies along the Norwegian coast to Spitsbergen (65-79 °N) for four seabird species (Atlantic puffin, black-legged kittiwake, and common and Brünnich's guillemots) and asked how timing varied between species and over a large spatial scale.

Because spring comes later to higher latitudes, we expected to see later breeding at higher latitudes, and that is what we found. However, different species had different patterns of breeding synchronicity, or how closely in time the individuals at each colony were breeding. For the kittiwake, breeding synchronicity increased with increasing latitude. This suggests that

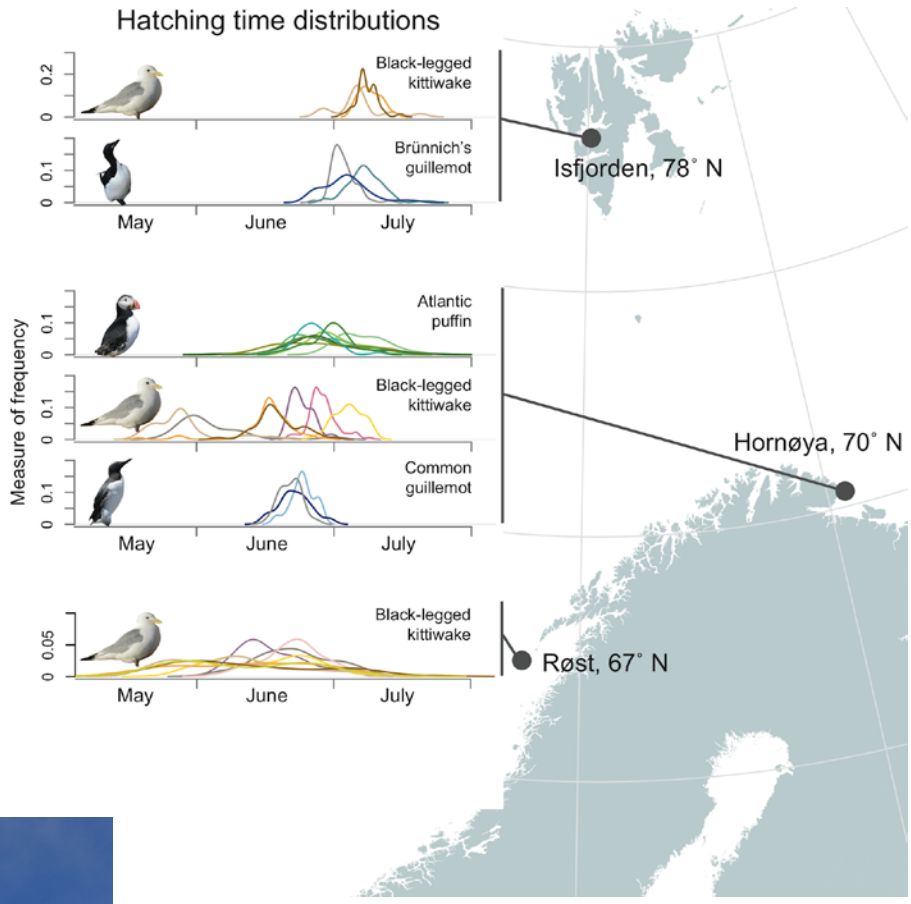
Black-legged kittiwakes on their characteristic nests.
Photo: Sébastien Descamps, Norwegian Polar Institute

Black-legged kittiwakes and Brünnich's guillemots with chicks on Spitsbergen. Guillemots lay their eggs on bare rock. All the nest material seen here comes from the kittiwake nests.
Photo: Øystein Varpe, University Centre in Svalbard

as the summers get shorter, the birds breed within a narrower window of time. Tycho Anker-Nilssen, who leads monitoring efforts at Røst in Lofoten, one of the more southern latitudes represented in the study, shared his first-hand accounts: "In terms of weather, the window for nice breeding conditions is of course larger than further north, yet my feeling is that it also has very much to do with food availability. On top of this, it seems that extensive egg predation (especially by ravens) in parts of the colony acts to reduce clutch size and delay hatching for many pairs." So in low latitudes we see a wide range of hatching dates, and sometimes summers are also long enough for a new clutch to be laid if the first is lost. However, this may not be the case at the highest latitudes, such as on Spitsbergen.

In contrast to kittiwakes, two species of guillemots (Brünnich's and common) were breeding synchro-

Photo of Brünnich's guillemot: Sébastien Descamps, Norwegian Polar Institute, all others: Zofia Burr, University Centre in Svalbard



Black-legged kittiwakes with chick. *Photo: Tomas Aarvak*

PHENOLOGY

- The study of cyclical biological phenomena, often in relation to climatic conditions and the annual cycle
- An important focus as climate changes, because the timing of ecological interactions is impacted by climate and influences reproduction and survival
- Examples of measurable phenological events include timing of breeding, migration and molting in animals, and leaf budburst and flowering in plants

nously at all colonies in our study, not just at the highest latitudes. Sébastien Descamps, a biologist working at colonies in Isfjorden, comments on why we think we see this pattern. "On Spitsbergen, we see the guillemot chicks fledging quite synchronously, within a few days, which is likely advantageous from their perspective since predators such as foxes and glaucous gulls often go after the chicks for prey. Jumping all together decreases the probability of getting caught by a predator!" This strategy, known as "predator swamping", could explain why the guillemots schedule breeding synchronously at all study colonies, unlike the kittiwakes.

Puffin breeding times show a less distinct pattern than those of the other species. Unlike kittiwakes, puffins showed no significant change in synchronicity with increasing latitude, nor was breeding as consistently synchronous as it was for guillemots.

Our results tell us two main things: species differ in their timing strategies, and various components of timing (for example, breeding synchronicity vs average timing) are shaped by different processes. Given

Observer monitors nesting black-legged kittiwakes on Spitsbergen.
Photo: Øystein Varpe, University Centre in Svalbard

that species have different strategies to time their breeding, they will likely face different challenges when it comes to successfully raising their chicks. Perhaps under changing environmental conditions, some species will have difficulties adjusting to new conditions and end up breeding at sub-optimal times, thereby risking reduced reproductive success.

FURTHER READING

Burr ZM, Varpe Ø, Anker-Nilssen T, Erikstad KE, Descamps S, Barrett RT, Bech C, Christensen-Dalsgaard C, Lorentsen S-H, Moe B, Reiertsen TK, Strøm H (in press) Later at higher latitudes: large-scale variability in seabird breeding timing and synchronicity. Ecosphere

Researchers from many institutes and disciplines joined forces for this project. Several of the collaborators are responsible for key sites in the SEAPOP programme, which has been producing important results on seabird population dynamics for more than a decade.

Zofia M. Burr, UNIS and the University of Bergen
Øystein Varpe, UNIS and Akvaplan-niva
Tycho Anker-Nilssen, NINA
Kjell Einar Erikstad, NINA and NTNU
Sébastien Descamps, NPI
Robert T. Barrett, UiT The Arctic University of Norway
Claus Bech, NTNU
Signe Christensen-Dalsgaard, NINA and NTNU
Svein-Håkon Lorentsen, NINA
Børge Moe, NINA
Tone Kristin Reiertsen, NINA
Hallvard Strøm, NPI

UNIS – University Centre in Svalbard
NTNU – Norwegian University of Science and Technology
NINA – Norwegian Institute for Nature Research
NPI – Norwegian Polar Institute

Michel d. S. Mesquita // Uni Research Climate, and Bjerknes Centre for Climate Research
Kjell Einar Erikstad // NINA – Norwegian Institute for Nature Research

The atmosphere's role in the rise and fall of the guillemot

What killed the guillemots? In a north Norwegian colony of common guillemots at Hornøya, fewer than one in three birds survived the winter of 1986/87. The obvious cause was a lack of fish, but thanks to the emerging science of climate ecology, we now know that weather patterns may also have played a part.

CLIMATE ECOLOGY

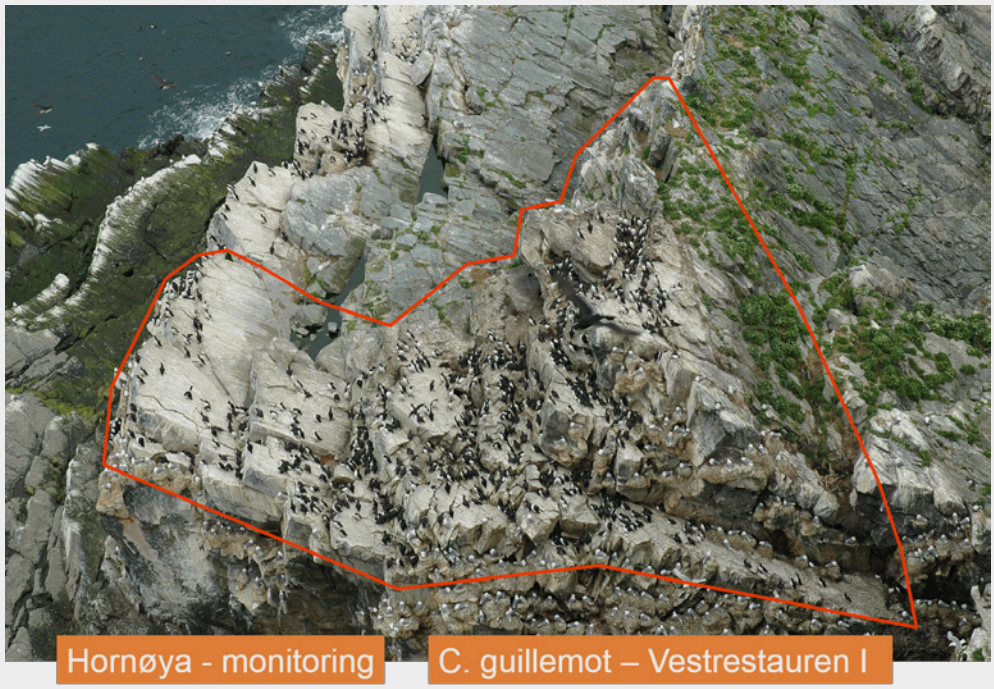
The earth system is a complex puzzle of multifarious components that also interact in many ways. Climate ecology is a relatively new discipline that tries to make sense of how climate variability and change affects ecosystems. One of the main challenges is to determine cause and effect. In order to explain that a climate covariate may affect an ecological variable, we need to consider the climate system as a whole. An international team of ecologists and climatologists set up at NINA recently published an article in *Frontiers of Ecology and Evolution* describing how climate dynamics could explain variations in the guillemot population.

A COMPLEX JIGSAW

In the *Frontiers* paper, we tried to take into account the climate system as a whole by building on earlier work by Kjell Einar Erikstad and others, where a full mapping of the modulation of the growth rate of the common guillemot was done with respect to fish stock. We complemented those data through the study of atmospheric processes, in such a way that we could have two perspectives: from the ocean and the atmosphere. This allowed us to see the Hornøya 1986/87 crash and the variability in growth rate from different points of view. We began piecing together a complex jigsaw.

Our analysis used robust approaches, common to climate dynamics. One valuable technique is to use "point maps", where correlations between an ecological variable and a climatological covariate are calculated for locations ("points") all around the globe. This technique was pioneered in the late 1960s by the famous Norwegian climatologist Jacob Bjerknes, who used it to explain the El Niño Southern Oscillation. Point maps helped him find "hotspots" or regions around the globe that are linked to one another - what we call teleconnectivity.

The North Atlantic Oscillation (NAO) is a teleconnection pattern that has often been used in climate

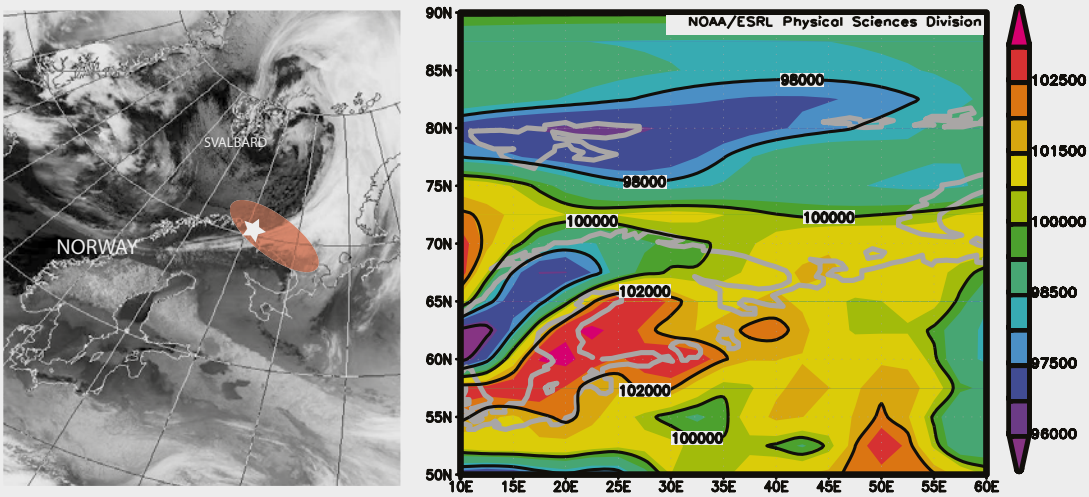


A monitoring plot for common guillemots. This is one of 16 such plots at Hornøya, where birds are counted from photos five times each year at different stages of the breeding season to get credible estimates. The results are used to model change in population size over years.

Photo: Robert T. Barrett, UiT The Arctic University of Norway

ecology. Simply put, the NAO is variations in how great a difference in air pressure we see between regions in the North Atlantic. But reality is not simple. The NAO is only one of many teleconnection indices in the Northern Hemisphere. It is also affected by other factors in the climate system, such as changes in sea-ice conditions or storms. In addition, the relationship between the NAO and seabird population growth rates is highly variable, both within and across species.

We therefore used a different approach - point maps - to identify the climate dynamics and teleconnectivity patterns associated with the growth rate of common guillemots and sea level air pressure. It was only after this step was complete that we looked for a climate covariate to use in a population model. This is like finding all the patterns in the jigsaw puzzle first (edge pieces, blue pieces, striped pieces) before putting them together, instead of taking a specific piece and trying to fit the others around it.



WEATHER CONDITIONS ON 14 JANUARY 1987

Left: Satellite image showing a storm system in the Barents Sea, centred around Svalbard, with a frontal structure that reaches mid-Norway (star marks Hornøya; wintering areas of common guillemots shown in orange). Right: A strong low pressure system, with core pressure less than 980 hPa (right, units: Pa for Pascal).

Satellite image provided by Prof. Humberto Barbosa (UFAL, Brazil, www.lapismet.com)

Pressure chart provided by Physical Sciences Division, Earth System Research Laboratory, NOAA, Boulder, Colorado, USA. http://www.esrl.noaa.gov/psd/

CAUSE-AND-EFFECT CORROBORATED BY PHYSICAL MECHANISMS

Our results showed that the NAO pattern was not a visible feature in point maps. So, if we had found a correlation between the NAO and the growth rate of common guillemots, this would not have been corroborated by the physical mechanisms - and the correlation would have been spurious. This means that *other* atmospheric systems are at play in influencing the guillemot growth rate.

Through our analysis, we found that an anomalous winter low-pressure system over the Barents Sea is associated with higher population growth rates: low pressure brings storms into the region and creates warmer conditions. The opposite is true in winters with anomalous high-pressure systems over the Barents Sea. The crash in 1986/87 could be explained by the extreme conditions that winter: a severe anomalous high-pressure system over the region and polar lows.

Two common guillemots photographed on Bjørnøya. One of these birds is a "bridled guillemot" with a white eye ring and a stripe. Despite this distinct difference, both birds are of the same species.

Photo: Hallvard Strøm, Norwegian Polar Institute

HORNØYA'S UNIQUE DATASET

It is worth mentioning that to make the study robust we had to have a long time series. In fact, the World Meteorological Organization recommends the use of at least 30 years of data for climatological analyses. So our study was made possible through the diligence of many scientists from the University of Tromsø and NINA, who have been collecting data at Hornøya since the 1980s.

It has been clear since the early 19th century that long-term data series on seabirds can be an important tool for understanding environmental impacts. However, long term monitoring is both time-consuming and expensive. Along the way, funding problems led to gaps in data coverage; at times, entire time series were discontinued. We are now fully aware that the long-term monitoring of demographic data of seabird populations may provide insight into the ecological consequences of anthropogenic climate change on the marine environment and give valuable information to governmental authorities and environmental agencies. The Hornøya case has been a success and we hope the monitoring there can continue for many years to come.

FUTURE OUTLOOK

Our study does not stop here. Many questions remain to be answered, such as how multiple colonies (and multiple species) interact with different oceanic and atmospheric variables. This synchronisation aspect would take into account the ecological-climatological system as a whole and help us put more pieces in the puzzle. It is a daunting task, but a very exciting one.

FURTHER READING

Erikstad KE, Reiertsen TK, Barrett RT, Vikebø F, Sandvik H. (2013) Seabird-fish interactions: the fall and rise of a common guillemot *Uria aalge* population. *Marine Ecology Progress Series*, 267-276

Mesquita MDS, Erikstad KE, Sandvik H, Barrett RT, Reiertsen TK, Anker-Nilssen T, Hodges KI, Bader J. (2015) There is more to climate than the North Atlantic Oscillation: a new perspective from climate dynamics to explain the variability in population growth rates of a long-lived seabird. *Frontiers in Ecology and Evolution*. http://journal.frontiersin.org/article/10.3389/fevo.2015.00043

Hallvard Strøm and Sébastien Descamps // Norwegian Polar Institute
Børge Moe and Per Fauchald // Norwegian Institute for Nature Research
Morten Ekker // Norwegian Environment Agency

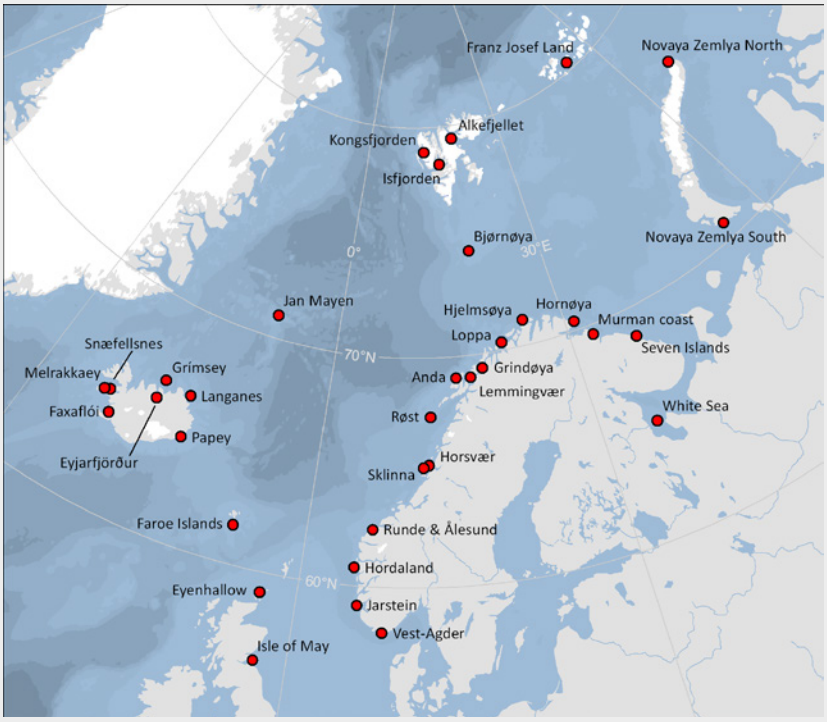
SEATRACK – Where do seabirds go after the breeding season?

Most seabirds spread over vast areas in the non-breeding season. Until now, these movements have been difficult to study, but in a new programme called SEATRACK, birds are being fitted with tiny logging devices that will give us clues on where they go in winter and what threats they face there.

Together with neighbouring countries, Norway supports some of the largest seabird populations in the world. Norway alone has more than 5.5 million breeding pairs on the mainland and in Svalbard, and many of these populations are of international importance. Seabirds stay close to their breeding colonies in summer, but outside the breeding season they can roam far and wide. A good example is the arctic tern, which nests in the Arctic, but winters in the seas around Antarctica. This small bird flies over more than 80 000 kilometres of open ocean every year.

Many of Norway's seabirds migrate away from the Norwegian Sea in the winter, but are replaced by birds from neighbouring countries, especially Russia, Iceland and the United Kingdom. This means that birds from many breeding colonies and countries winter in Norwegian waters. To assess the impact an oil spill might have, for example, we need to know which species and populations are likely to be affected, and where they come from. Such knowledge is important for oil spill contingency planning; an oil spill would have different effects on a numerous, thriving population than on one that is small and in decline. Knowledge about seabirds' migratory habits and spatial ecology outside the breeding season is crucial not just for sound management, but also for other sectors of society, including industry and scientific research.

Many seabird species have been declining in recent years, and several are on national and international Red Lists. A decline may have to do with conditions at the summer nesting sites, for example lack of food, but it could also be attributed to conditions along the birds' migratory routes. Migration patterns have been difficult to study, as it has not been possible to follow seabirds once they have left the breeding colonies in early autumn. But now, new technology in the form of miniature, bird-borne light-level logging devices (or geolocators) is revolutionising this field.



Map of the breeding colonies included in SEATRACK where birds are instrumented with light-level loggers.

Map: Norwegian Polar Institute/Anders Skoglund

The species included in SEATRACK, their ecological group, and the number of colonies in the Barents Sea, the Norwegian Sea and the North Sea where birds are tagged.

		Number of colonies		
Species	**Ecological niche**	**Barents Sea**	**Norwegian Sea**	**North Sea**
Common guillemot *Uria aalge*	Pelagic diving	4	4	1
Atlantic puffin *Fratercula arctica*	Pelagic diving	5	5	2
Brünnich's guillemot *Uria lomvia*	Pelagic diving	7	2	0
Little auk *Alle alle*	Pelagic diving	3	-	-
Black-legged kittiwake *Rissa tridactyla*	Pelagic surface feeding	10	4	1
Lesser black-backed gull *Larus fuscus*	Pelagic surface feeding	2	4	1
Northern fulmar *Fulmarus glacialis*	Pelagic surface feeding	3	3	1
Herring gull *Larus argentatus*	Coastal surface feeding	3	6	2
Glaucous gull *Larus hyperboreus*	Coastal surface feeding	3	1	0
European shag *Phalacrocorax aristotelis*	Coastal diving	3	3	2
Common eider *Somateria mollissima*	Coastal benthic feeding	4	4	1

Geolocators are tiny, lightweight (1-2.5 g) tracking devices that can be mounted on the bird's leg ring. The logger continuously stores light intensity data, from which we can calculate the bird's daily positions (see text box). The bird has to be recaptured so we can download the data, but most seabirds return to the same nesting site year after year, which makes this technology well suited for obtaining information about where an individual has been since last time it was tagged.

Knowing where the seabirds are at any time enables us to study which environmental factors (both natural and man-made) affect the birds outside the breeding season and what consequences they have for the demography and development of breeding populations. Insight into the seabirds' winter ecology will help us understand the major population changes we have seen, and what changes we can expect to see in the future.

The geolocator technology is now being used in many studies, but to fully exploit its potential, we need coordinated efforts that cover a representative sample of species and colonies - and include a sufficient number of birds. That is where SEATRACK comes in: SEAbird TRACKing is a four-year programme to map Norwegian seabirds' spatial distribution and movements outside the breeding season - and at the same time follow bird populations from neighbouring countries that enter Norwegian waters. To do this, we annually mount light-level loggers on more than 2 000 birds from 11 species in more than 30 breeding colonies in Norway (including Svalbard and Jan Mayen), Russia, Iceland, the Faroe Islands and Great Britain. By monitoring individual birds over several seasons, we can learn more about variations in which areas the seabirds use, and whether certain areas are particularly important. The species included in the programme have been chosen on the basis of their ecological role,

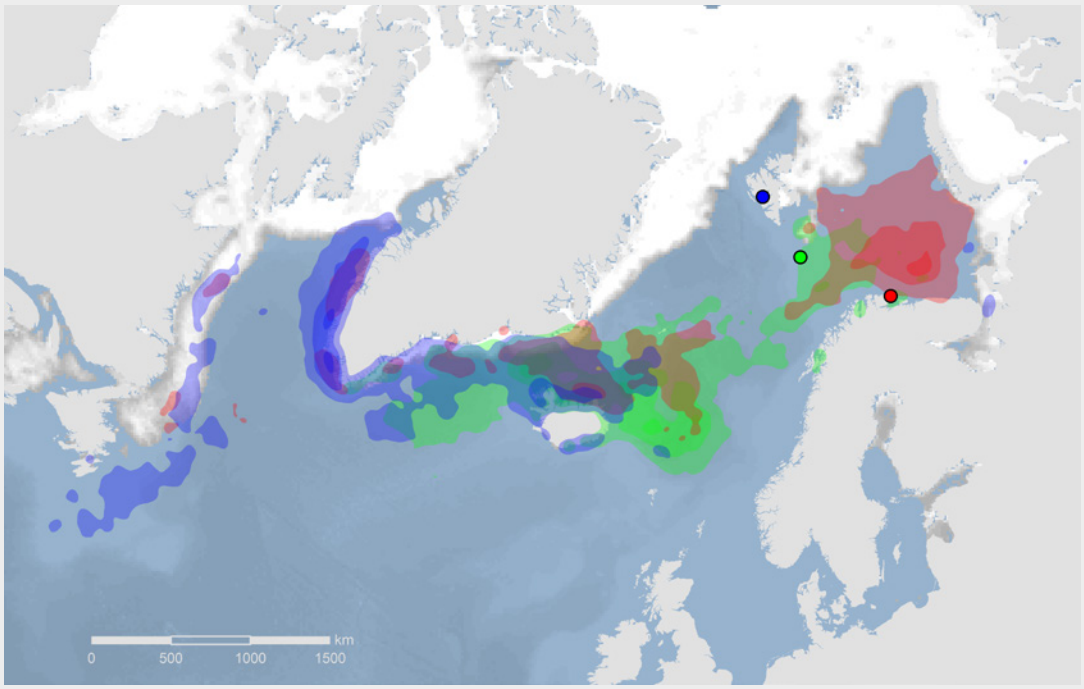
Through the SEATRACK programme, more than 6 000 birds will be caught and fitted with light-level loggers in this large-scale project designed to map migratory routes and wintering areas, and to gain better understanding of which environmental factors affect the birds outside the breeding season.

Photo: Hallvard Strøm, Norwegian Polar Institute

distribution and occurrence within each sea area. The programme will provide completely new knowledge about the seabirds' spatial ecology and behaviour in the Barents, Norwegian and North seas, reveal which breeding populations the birds belong to, their migratory routes and wintering areas, and how these vary over time.

Since SEATRACK will be producing knowledge required by many sectors, it is being financed jointly by the Ministry of Climate and Environment, the Ministry of Foreign Affairs, and the Norwegian Oil and Gas Association, along with seven corporations in the energy sector (Statoil, Eni Norway, ConocoPhillips, Total, DEA Norway, Det Norske Oljeselskapet, and GDF SUEZ). The programme is headed by the Norwegian Polar Institute in collaboration with the Norwegian Institute for Nature Research and the Norwegian Environment Agency. SEATRACK involves close cooperation with specialists in each country, and each participating institution contributes significantly. The programme has a small, full-time project staff consisting of a coordinator, a technician and a doctoral student. SEATRACK is organised as a new module within the seabird programme SEAPOP (www.seapop.no) to make use of the latter's well-established logistics. In addition, SEAPOP's data on the demographics of the instrumented birds and the breeding populations to which they belong will be crucial in the analyses of SEATRACK's results.

Apart from disseminating new knowledge through scientific publications, the programme has several deliverables of relevance to the oil industry and environmental management. Maps are of key importance: maps of the various species' distribution through months, seasons and years, and maps that show the breeding sites of the birds present in a given area at a given time. This kind of information is highly relevant for environmental risk assessments and impact assessments, and for investigations in the wake of specific events. It is also particularly valuable for the oil industry, as it enables the impact of a potential accident to be calculated at bird population level, and can aid in dimensioning an optimum response in oil spill contingency planning. These products will be delivered via an online web solution (http://www.seapop.no/no/seatrack/) that will become operational in 2016.



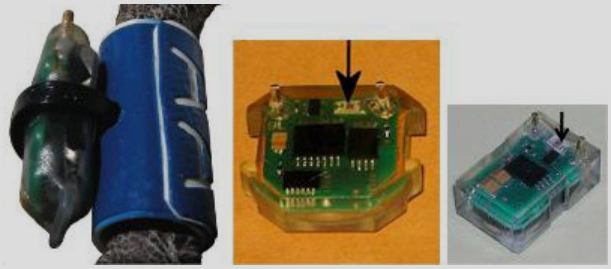
Distribution of Brünnich's guillemots in December – January. The birds come from three colonies, marked with dots. Blue: Isfjorden; Green: Bjørnøya; Red: Hornøya. The birds from Isfjorden overwinter mainly along the southwest coast of Greenland, the birds from Bjørnøya in the seas around Iceland, while the birds from Hornøya spend the winter in the Barents Sea.
Map: SEATRACK/Benjamin Merkel

HOW DOES A LIGHT-LEVEL LOGGER WORK?

A light-level logger, or geolocator, is a miniature electronic device that is used to track a bird's migratory movements. It contains a light sensor, memory card, battery and connectors – all encapsulated in a waterproof epoxy package. The logger can easily be attached to an ordinary leg ring and does not cause the bird any significant inconvenience. It measures light intensity every minute throughout the day. The bird's position can be calculated from the duration of daylight (latitude) and the time at mid-day (longitude). This simple technology allows the logger to function for 1 to 5 years even with small batteries. Weighing only 1 to 2.5 grams, it can be used on small/medium to large seabirds. The bird must be recaptured and the logger retrieved in order to download the data. The processed data give the bird's position with an average error of about 200 km. Because of their light weight and low cost, light-level loggers have found many applications and are used in many scientific research projects.

Light-level loggers are small, lightweight devices that can be attached to a bird's leg ring (left). The photographs show three different models. The arrow indicates the location of the light sensor.

Photos: Tycho Anker-Nilssen, Norwegian Institute for Nature Research



Linda Hanssen and Therese Haugdahl Nøst // NILU – Norwegian Institute for Air Research

Environmental toxins and you

Picture the world from space at night. Points of light show where humans live. They also show where most environmental toxins are: right where humans are. But toxins spread, too: outward to remote areas, borne by ocean currents and wind; and inward into your own body. Did you know they were there?

ALL HUMANS CARRY ENVIRONMENTAL TOXINS in their body. Some carry more, some less, depending on how old they are, where they live, what they eat, and many other factors. But what is an environmental toxin? The precise scientific term, "persistent organic pollutant" (POP), gives a better description of what it is all about. Environmental toxins are *persistent* and if they degrade at all in the environment, they do so slowly. Organic environmental toxins are man-made and can have harmful effects on the environment and in humans. They also bioaccumulate, which means that organisms take up toxins faster than they can get rid of them, and the toxin concentration increases over time.

Where do environmental toxins come from? Some are formed as by-products of industrial processes (dioxins), others are synthesised on purpose (pesticides), and others were invented by accident (perfluorinated organic compounds) before being put to use in industry.

The group of environmental toxins that has been most in focus over the years is polychlorinated biphenyls (PCBs). PCBs were first synthesised in the 1930s and quickly became popular because their properties made them ideal for use in a number of industrial applications, for example in paint, plastics and electrical transformers.

Emissions to the environment through production and use led to the PCBs ending up in the food chain. These substances have an affinity for fat (we say they are *lipophilic*), and since marine food chains contain a great deal of lipids, the PCB concentrations in marine mammals, oily fish and birds' eggs have been high. International agreements restricting or even prohibiting the production and use of PCBs have resulted in a decrease in concentrations of PCBs in the environment and in humans.

According to Miljostatus.no, "PCBs can weaken the immune system, which increases susceptibility to infection and disease. Different PCB compounds can damage the nervous system, cause cancer of the liver and reduce fertility. Foetuses and infants are most sensitive to the effects. PCBs have a negative impact on humans' learning ability and development." Other effects have also been indicated in studies of human populations exposed to low doses, although the effects are often unclear.

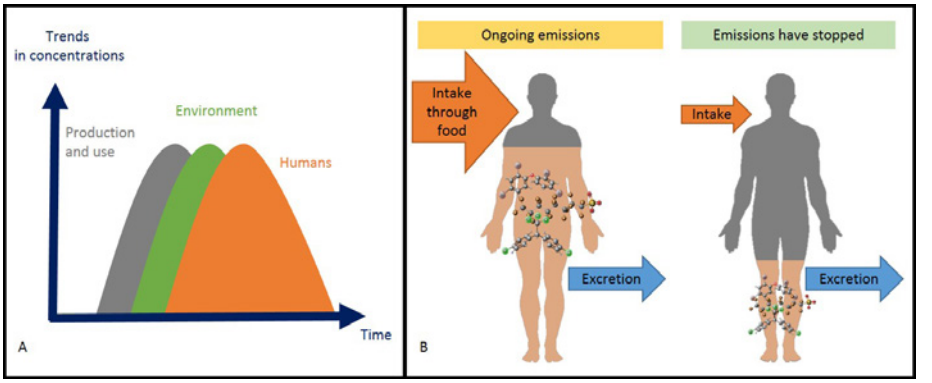
EFFECT STUDIES REQUIRE DATA ON EXPOSURE

To be able to study the effects of environmental toxins on humans, we need to have good knowledge of human exposure to them. There is no clear connection between the concentration of PCB in blood and its effect on the body. There are several reasons for this. Most epidemiological studies have measured the content of PCB in the blood at one particular point in time. But the group studied may have consisted of both old and young, women and men. Individuals, each with a unique personal history, whose bodies may contain completely different amounts of PCB. Conclusions have thus been drawn from that point in time, but time is also an important factor.

PCB emissions have risen and then fallen again over time, and the concentrations of PCBs in the environment and in humans have done the same. As long as PCB intake is high,

Grossly simplified, the graph shows how PBC production, emissions to the environment and concentrations in humans are correlated. As concentrations in the environment rise and fall, the concentrations in humans follow after a time lag.

Food is currently our main source of environmental toxins. High intake of an environmental toxin gives increasing concentrations in the body. When intake is reduced, the amount in the body will also decrease over time.



the concentrations will increase in the body, but if emissions are low and human intake goes down, the concentrations in an individual will fall over time. This conclusion is supported by model calculations based on emissions and measurements of concentrations in blood. Thus, time is an important parameter for assessing exposure and evaluating effects.

A person's lifetime exposure to environmental toxins depends on when he or she was born in relation to peak emissions. Let's use PCBs as an example: a baby born in 1940 was exposed to lower concentrations before birth than a baby born in 1980, when emissions were at their peak. Now, in 2016, the total amount of PCBs may be *higher* in the individual born in 1940 (who has lived forty years longer) but the baby from 1980 had higher *prenatal* exposure to environmental toxins than the baby from 1940. To be able to understand the effects, we must take into account the emissions that lie behind human exposure.

We know that the foetus is exposed to environmental toxins through its mother during pregnancy, as these toxins have been found in blood from the umbilical cord and in the newborn's first stool. In addition, lipophilic environmental toxins like PCBs are present in human breastmilk. So individuals are exposed from very early in life. (Just to be absolutely clear, we recommend breastfeeding nonetheless, as breastmilk contains many other valuable nutritional substances that are important for the child!)

So why are we still so concerned about PCBs, when their new use has not been permitted since the 1980s? In Norway, although PCB-containing products and waste have been collected for several years now, there are still an estimated 100 tonnes of PCBs in products and buildings in Norway (http://www.miljostatus.no/PCB). And PCB is just one in the multitude of chemicals we have all around us. But since so much research has been done on PCBs, we can use our knowledge about their environmental fate and human exposure when studying other environmental toxins. The fact that human exposure to PCBs is so closely correlated with emissions is important, and is probably also true for other substances. In recent years, researchers working on environmental toxins have been interested in cocktails - and we don't mean fancy drinks. We mean toxic cocktails - the mixture of chemicals our blood contains. There are indications that environmental toxins can influence each other's effects - sometimes enhancing them, sometimes counteracting them. We can do cause-and-effect studies in the laboratory, seeking correlations between one type of environmental toxin and its effect, but will the results hold true in the real world, where many other toxins are also present? Thorough knowledge about environmental toxins in human blood and how they change over time is crucial for cause-and-effect studies.

FURTHER READING:

Nøst TH, Breivik K, Fuskevåg O-M, Nieboer E, Odland JØ, Sandanger TM. (2013) Persistent Organic Pollutants in Norwegian Men from 1979 to 2007: Intraindividual Changes, Age–Period–Cohort Effects, and Model Predictions. Environmental Health Perspectives http://dx.doi.org/10.1289/ehp.1206317

Nøst TH, Breivik K, Fuskevåg O-M, Nieboer E, Odland JØ, Sandanger TM. (2015) Estimating Time-Varying PCB Exposures Using Person-Specific Predictions to Supplement Measured Values: A Comparison of Observed and Predicted Values in Two Cohorts of Norwegian Women. Environmental Health Perspectives http://dx.doi.org/10.1289/ehp.1409191

Agneta Fransson, Peter Thor and Allison Bailey // Norwegian Polar Institute
Melissa Chierici // Institute of Marine Research

Ocean acidification state in Kongsfjorden

Kongsfjorden must be one of the most breathtaking places on earth. With its icy water, spectacular mountains, and mighty glaciers, it epitomises the pristine Arctic. But something in the crystal clear air is affecting the water in a way that may spell trouble for the organisms in the fjord.

In recent years, Kongsfjorden has been through major changes due to a warming climate, such as thinning of sea ice and decreased sea ice extent. Its glaciers are retreating and more warm Atlantic water enters the fjord than previously. This affects water temperature, melting processes and surface stratification, all of which have important consequences for biogeochemical processes and the marine ecosystem. But our focus is on pH and carbonate ions in the fjord's water and how they are changing.

When the amount of carbon dioxide in the atmosphere increases, the ocean becomes less basic (see fact box). There is reason to believe that the process differs in Atlantic and Arctic conditions. That is where Kongsfjorden comes in. This 20-kilometre-long fjord in western Spitsbergen has a shallow inner part of less than 100 metres depth and a sill of about 20 metres. Further out, the fjord seabed plunges to 300 metres and there is no sill. Two tide-water glaciers (Kronebreen and Kongsbreen) and some rivers supply inner Kongsfjorden with glacial meltwater and create cold and fresh surface water, which make it comparable to Arctic conditions. The outer parts of Kongsfjorden are affected by warm, salty Atlantic water. These two contrasting conditions result in large differences in physical and chemical characteristics and make the fjord a natural laboratory to investigate impacts of climate change (effects of warming, freshening), ocean acidification (OA), and the processes driving the evolution and adaptation of the marine ecosystem.

Since 2012, we have performed field studies in Kongsfjorden in winter and summer, collecting seawater from several depths in the water column and at several locations from the glacier front to the outer fjord. We have also collected sea ice and glacial ice. Seawater samples are analysed for pH, carbon dioxide and carbonate ion content to investigate how the acidification state varies from season to season and year to year. Our results show that freshwater supply from glaciers, sea-ice melt and river runoff accelerates OA. In other words, acidification appears to be faster in Arctic water. Atlantic water is generally warmer than the freshwater in the fjord and contains more carbonate ions.

To assess the effects of OA on the Kongsfjorden ecosystem, we are conducting a series of experiments on key species in the ecosystem. Copepods of the *Calanus* genus play a pivotal role in the pelagic ecosystem as the main prey for most larval and juvenile fish, but

Sea ice sampling using an ice corer.
Photo: Melissa Chierici, Institute of Marine Research

also for baleen whales and some seabirds. Thus, they are the main conveyor of organic matter from primary production to the upper trophic levels. So far, our efforts have focused on *C. glacialis*, the most abundant *Calanus* species in the fjord. We capture copepods in the fjord and incubate them at a pH range covering global predictions from the present to 2300. In the laboratory, we measure changes in energy intake, energy expenditure, expression of specific genes involved in stress responses and the resulting changes in a variety of metabolites. This enables us to establish what we call pH reaction norms, which describe how a specific trait changes with changing pH. Reaction norms are very useful as input into models predicting the flow of energy through food webs and development of populations in an acidified future ocean. Within the Fram Centre Ocean Acidification Flagship we are presently refining computer models to help us predict the effects of OA.

Carbonate ions are essential for the formation of the calcium carbonate shells of some organisms. While copepods do not use calcium carbonate in their shells, pteropods do. Therefore we also collect pteropods (butterfly snails) for analysis. The thin calcareous shell of these beautiful organisms is especially vulnerable

Calanus glacialis.
Photo: Allison Bailey, Norwegian Polar Institute

The pteropod *Limacina helicina.*
Photo: Hopcroft UAF/CoML

Water sampling under the ice.
Photo: Agneta Fransson, Norwegian Polar Institute

to warming and ocean acidification because they have a limited ability to control changes in pH, and suffer under low carbonate ion content: both factors reduce their ability to form their shells. In this project, we focus on the pteropod *Limacina helicina* and measure shell condition in terms of thickness, porosity and chemical composition.

The results from Kongsfjorden will be compared with results from other fjords and coastal systems in the Arctic and northern Norway with different characteristics. In this way, we will explore the connection between environments and the effects on marine organisms.

FURTHER READING:

Fransson A, Chierici M, Nomura D, Granskog MA, Kristiansen S, Martma T, Nehrke G. (2015) Effect of glacial drainage water on the CO_2 system and ocean acidification state in an Arctic tidewater-glacier fjord during two contrasting years. Journal of Geophysical Research-Oceans, 120, doi:10.1002/2014JC010320.

Thor P, Halsband C, Browman H. (2014) Ocean acidification - CO_2 effects in Northern waters. Fram Forum 2014, pp 40-44. Read online at http://issuu.com/framcentre/docs/framforum-2014-web

Fransson A, Chierici M, Granskog M. (2013) Understanding ocean acidification - Is the Arctic turning acid? Fram Forum 2013, pp 10-13. Download from https://issuu.com/framcentre

PROJECT INFORMATION

The research project described here is part of the Ocean Acidification Flagship programme at the Fram Centre and was initiated in 2012. The project is interdisciplinary: chemical and physical oceanographers and marine biologists from the Norwegian Polar Institute and the Institute of Marine Research collaborate to resolve trends and effects of ocean acidification in the arctic marine ecosystem. In summer, samples are taken in collaboration with the MOSJ project (Environmental Monitoring of Svalbard and Jan Mayen), usually from the RV *Lance*, and experiments to assess the biological effects of OA are conducted at the Kings Bay Marine Laboratory. In winter, sampling is done from small boats stationed in Ny-Ålesund and the seawater samples are transported to the Institute of Marine Research in Tromsø for analyses of ocean acidification state.

Sampling for calanus and pteropods.
Photo: Ella Guscelli, Institute of Marine Research

WHAT IS OCEAN ACIDIFICATION?

Ocean acidification is an indirect consequence of increased CO_2 levels. Of the CO_2 humanity has released to the atmosphere, the ocean has taken up about a third. The resulting changes the marine CO_2 system include decreased ocean pH and carbonate ion content. This phenomenon, called ocean acidification (OA), has raised a number of questions about the effects on organisms and the marine ecosystem. The cold, relatively fresh waters of the polar oceans are particularly sensitive to changes, since they already have low carbonate ion concentrations and cold water can take up more atmospheric CO_2 than warm water. This is why polar seas are the first to show a decrease in pH. Acidification is detrimental to organisms such as shellfish and corals because it dissolves the calcium carbonate in their shells or skeletons. It also threatens other marine organisms by increasing the amount of energy they must spend to maintain acid-base balance in their cells.

A typical catch from the sampler.
Photo: Ella Guscelli, Institute of Marine Research

Åshild Ø. Pedersen // Norwegian Polar Institute
Audun Stien // NINA – Norwegian Institute for Nature Research
Eeva Soininen and Rolf A. Ims // UiT The Arctic University of Norway

Climate-Ecological Observatory for Arctic Tundra—Status 2016

The arctic tundra is challenged by climate change — more so than most other ecosystems on Earth. The rapid shifts to new climate regimes may give rise to new ecosystems with unknown properties. These dramatic changes call for ecosystem-based monitoring of climate impacts on arctic food webs.

The Climate-Ecological Observatory for Arctic Tundra (COAT) is a response from five Fram Centre institutions to the urgent international calls for establishment of scientifically robust observation systems that enable real time detection, documentation and understanding of climate impacts on arctic tundra ecosystems. Between 2011 and 2013, a task force of 23 ecologists developed the scientific approach for the observatory, which is outlined in a comprehensive science plan (see text box for link and reference).

ECOSYSTEM-BASED OBSERVATORY

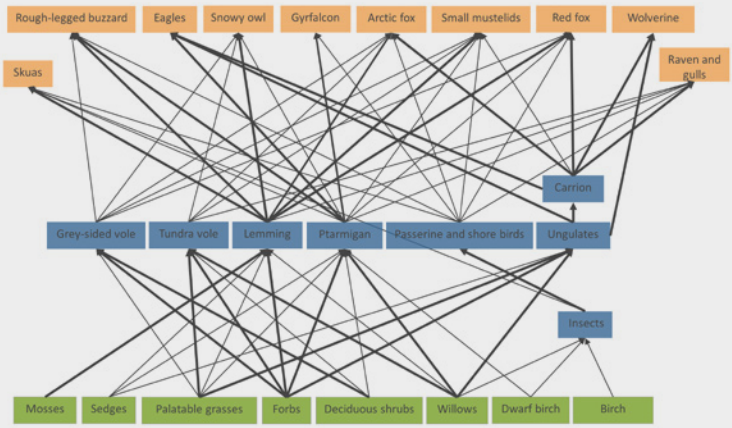
COAT is a system for long-term research on arctic terrestrial ecosystems. It uses a food-web approach, which combines research at the very forefront of climate-ecological science with management according to long-term adaptive protocols. Two Norwegian Arctic regions are in focus – the Low-Arctic Varanger Peninsula and the High-Arctic Svalbard – that harbour vast stretches of pristine wilderness with intact ecosystem functions and endemic biodiversity of great fundamental and societal significance. In a circumpolar perspective, these two regions provide pertinent contrasts in system complexity, climate and management regimes. COAT builds on and expands the ongoing research and long-term monitoring in both places.

CLIMATE IMPACT PATH MODELS

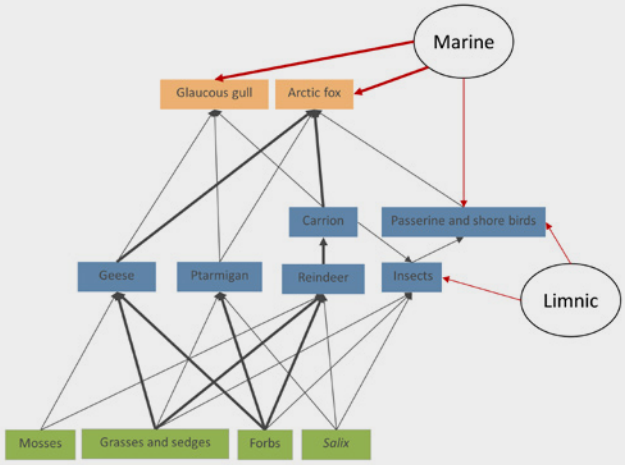
COAT aims to establish causal relations between components of the food webs that are particularly important to ecosystem functioning and/or management (response targets) and climate and management drivers (predictor targets). The likely paths for such causal relations are expressed in terms of conceptual "climate impact path models". The knowledge base for each of the seven models developed for COAT is outlined in the science plan. The models encompass all key species, functional groups and communities within the food webs and their mutual linkages. Examples of food web linkages are for instance predator-prey and plant-herbivore interactions, competition for food and habitats, and match or mismatch in timing of reproduction with food resources. The illustrations on page 38 and 40 show the approach theoretically, by using the conceptual model centred on the arctic fox in Svalbard, and we give a concrete example - the severe defoliation of sub-arctic birch forest after a recent outbreak of forest pest insects (geometrid moths) intensified by changes in spring temperatures (page 42).

Placing a photo box in the field.
Photo: Leif Einar Støveren, UiT The Arctic University of Norway

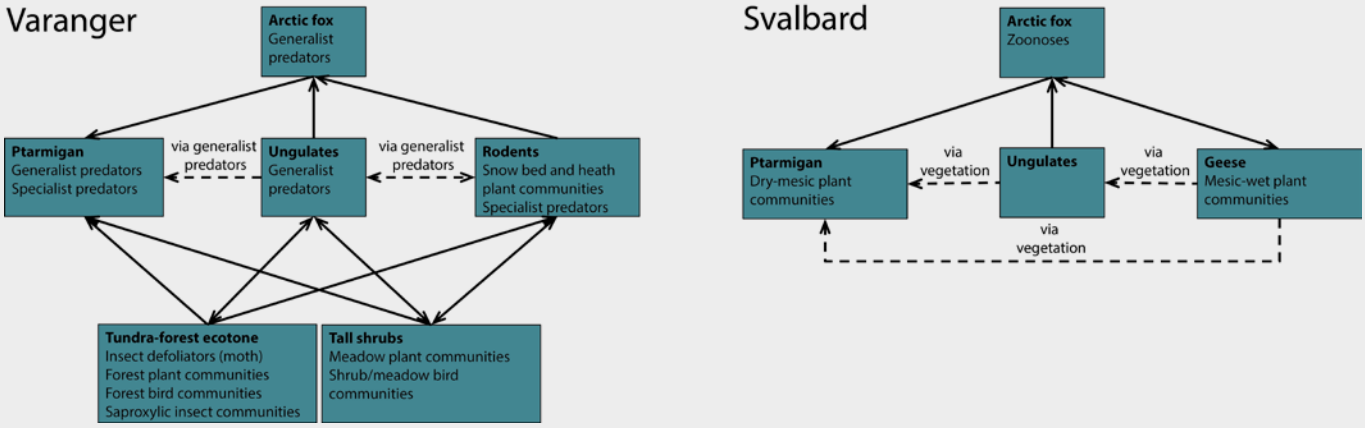
LOW-ARCTIC VARANGER PENINSULA



HIGH-ARCTIC SVALBARD



The plant-based food webs of the tundra in Low-Arctic Varanger Peninsula and High-Arctic Svalbard.



An outline of the seven food web modules in COAT (blue boxes) and the linkages within the two focal terrestrial ecosystems. The response targets of each module are listed within the boxes and the target that gives the module its name is in bold. Direct links between modules are shown as solid arrows; indirect links as dotted arrows. A vegetation module for Svalbard is under development.

Making field observations on a sunny summer day.

Photo: Kari-Anne Bråthen, UiT The Arctic University of Norway

The COAT science plan describes in detail the overall approach, the expectations for climate-ecosystem interactions for the different ecosystem components, as well as the state variables. The overall study designs are common for a suite of targets and state variables at spatio-temporal scales that allow us to discriminate natural variation from climate impacts on the ecosystem. The study methods range from field observations to remote sensing. COAT also aims to contribute to the development of new technologies that generate high quality data with a minimal environmental footprint. The data analyses encompass statistical and mathematical models, and development of appropriate modelling tools is an important outcome of COAT. Together, the combination of state-of-the art study designs, monitoring and analysis methods will enable COAT to answer both scientific and management questions.

THE COAT APPROACH

Ecosystem-based with focus on:

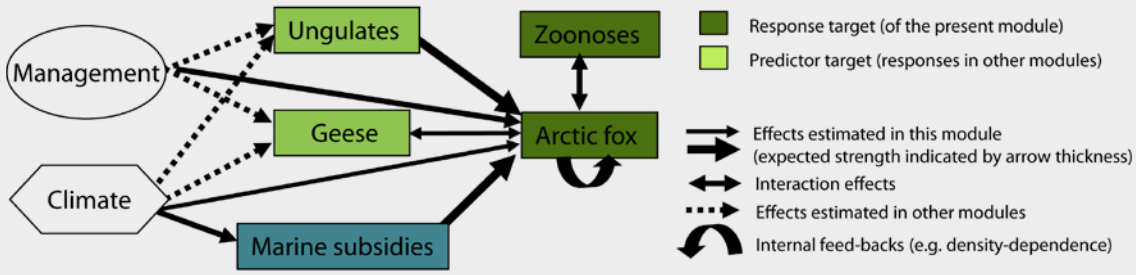
- Management relevance
- Key species and assemblages in the ecosystem
- Processes with a high sensitivity to climate change
- Active involvement of schools, local communities, stakeholders and management

Knowledge-based with focus on:

- Scientific design in data collection and analysis methods
- Development of predictive models for ecosystem responses to climate change

Adaptive with focus on:

- Continuous update of the knowledge base
- Continuous evaluation and update of the predictive models
- Updating design and analyses when new technology and methodology becomes available
- Updating design in response to changes in society's need for knowledge



The arctic fox "climate impact path model" predicts three climate impact pathways. One works though decreased sea ice extent, reducing arctic fox migration and exploitation of marine resources in winter. The two other pathways work indirectly through climate impacts on availability of key terrestrial prey species (Svalbard reindeer and geese). All changes in arctic fox population density, spatial distribution and behaviour are expected to influence how many of the foxes are infected with zoonoses – diseases that can spread to humans.

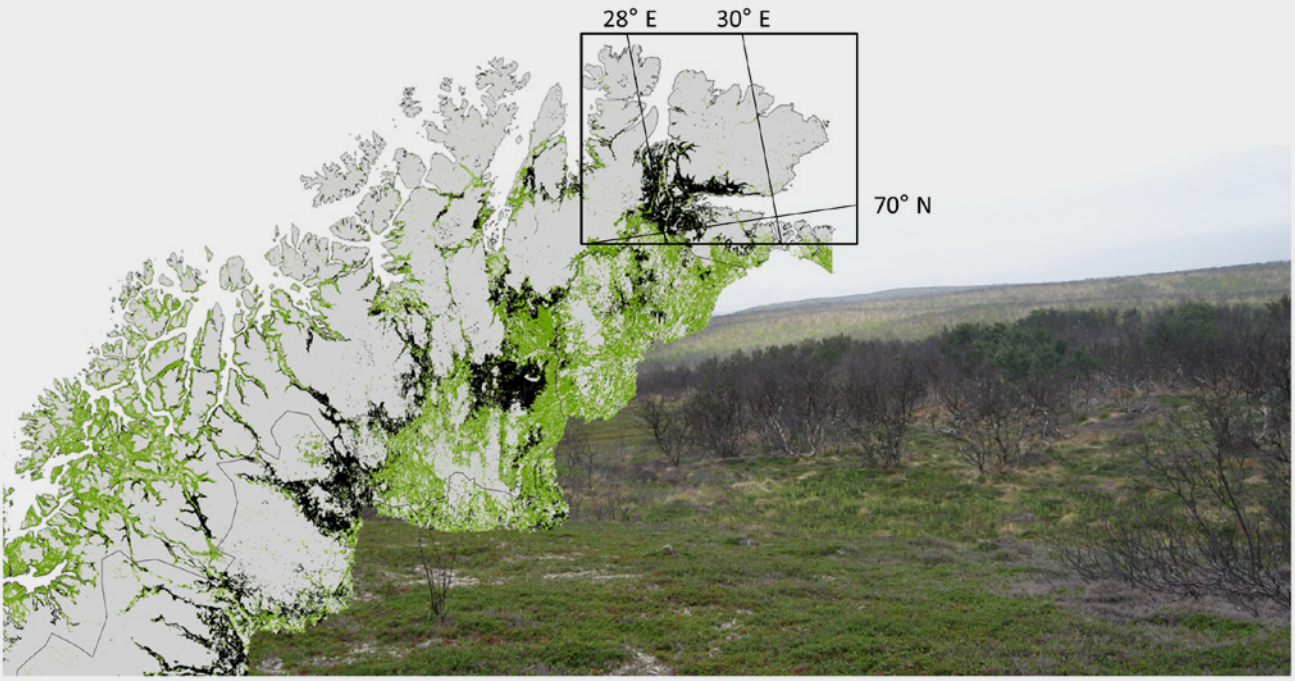
The COAT science plan also describes the *adaptive* approach: how new knowledge, technology, scientific questions and management goals will be incorporated into existing protocols in an iterative manner. COAT also aims to contribute to education at levels ranging from primary school to PhD courses. Ongoing initiatives are TUNDRA school net - a research-based school project for local arctic communities, and AMINOR - an interdisciplinary research school based at the Fram Centre.

START-UP OF "COAT INFRASTRUCTURE"

In autumn 2015, COAT was granted substantial funding to establish research infrastructure from the Norwegian Research Council (35 million NOK) and "Tromsø forskningsstiftelse" (10 million NOK). This funding will allow us to start up "COAT-infrastructure" during 2016-2020. "COAT Infrastructure" will implement and operationalise physical and electronic infrastructure related to *state variable instrumentation* (i.e. both food web and climate observation networks), *field logistics* and *data management solutions*. A scientific coordinator, together with researchers, technicians and IT services from Fram Centre institutions, will make this huge task possible. Successful data management and infrastructure coordination is essential for the long-term research project "COAT Science".

The infrastructure project will go through the stages of planning (2016), field implementation of instruments (2017 and 2018), and development and testing of the database solution (2016-2020). Field instruments will facilitate measurement of both *ecological variables* (for example through optical recording networks, telemetry equipment, herbivore exclosures) and *climate state variables* (i.e. automatic weather stations, ranging from temperature loggers to complete meteorological stations). Instruments will be distributed at spatial and temporal scales appropriate for estimating the weather pattern and ecological interactions of interest in the COAT modules.

Photo: Nicolas Lecomte, Norwegian Polar Institute



Defoliated sub-arctic birch forest in Varanger Peninsula following a severe moth outbreak. The overlaid map shows the birch forest belt of northern Fennoscandia with the COAT site in the northeast. Black shaded areas show birch forest affected by severe defoliation as detected by satellite during a recent outbreak (2002-2008), while green areas show forest with no or moderate defoliation.
Photo: Ole Petter L. Vindstad, UiT The Arctic University of Norway

Field logistics are essential for the large COAT field crews that operate in remote tundra areas in Varanger Peninsula and Svalbard. Crucial infrastructure components include mobile field stations, local storage facilities for equipment, and efficient means of transporting heavy field equipment and personnel. The success of "COAT Infrastructure" will depend on good cooperation among Fram Centre institutions in sharing of resources and close cooperation with stakeholders involved in management and conservation of arctic tundra.

"COAT Infrastructure" is essential for "COAT Science" – the long-term research program facilitated by the infrastructure. The long-term scientific endeavour will be fully operative in 2020.

THE COAT PROJECT INVOLVES FIVE FRAM CENTRE INSTITUTIONS:

- The Norwegian Institute for Nature Research
- The Norwegian Meteorological Institute
- The Norwegian Polar Institute
- The University Centre in Svalbard
- UiT The Arctic University of Norway

Photo: Leif Einar Støvern, UiT The Arctic University of Norway

THE COAT SCIENCE PLAN

- **Is a comprehensive review of the functioning of the terrestrial food webs in the Arctic with specific references to scientific knowledge about climate impacts**
- **Includes descriptions of "climate impact path models" that define climate-sensitive and management-relevant ecological targets, ecological and climatic state variables, sampling designs, and mathematical/statistical modelling approaches**
- **Contains protocols for updating prediction models, monitoring design, and methods in response to new knowledge, technologies, and societal priorities according to the paradigm of adaptive monitoring**

The COAT Science Plan is a peer-reviewed science plan that outlines a substantial expansion of ongoing and new long-term adaptive ecosystem monitoring based on food-web theory.

Read the Science Plan at www.coat.no/
Ims RA, Jepsen JU, Stien A, Yoccoz NG (2013) Science Plan for COAT: Climate-ecological Observatory for Arctic Tundra. Fram Centre, Tromsø

Eva Therese Jenssen // University Centre in Svalbard

The antique mountain peaks of Svalbard

The rugged mountains of northwestern Svalbard are not the product of erosion in the latest ice age. New findings show that these mountains formed much earlier and were protected by glacial armour for a million years. This turns current knowledge about the development of alpine topography on its head.

GLACIERS ARE THE MOST EFFECTIVE EROSION AGENTS and can change a flat landscape into an array of valleys and mountain peaks. In school we learn that the deep fjords and high peaks in many mountainous areas were caused by the several ice ages the Earth has gone through. Each new ice age has "washed away" evidence of previous glaciation periods.

GLACIAL "BUZZ SAWS"

Glaciers are known to act like "buzz saws", cutting mountains down to size. As mountain chains rise, the glacial buzz saw erodes, thus limiting growth. Current consensus has been that the high-relief mountain landscapes are the product of repeated glacial erosion over the entire Quaternary period of the past 2.5 million years.

The team of scientists from UNIS, University of Buffalo, University of Bern, Swiss Federal Institute of Technology in Zürich, University of Oslo and University of Gothenburg, recently published their findings in the prestigious journal *Nature Geoscience* - findings that are in stark contrast to what was previously believed.

The scientists spent several months on field campaigns in remote areas of northwestern Svalbard. They took rock samples from eight alpine summits and calculated the age of the bedrock surfaces with isotope dating using ^{10}Be (Beryllium), and ^{26}Al (Aluminium). The results show that these seemingly fragile mountain summits had been shielded from erosion.

ARMOUR OF ICE

The glacial buzz saw had minimal impact on these Svalbard peaks because the mountains have been protected by a thick layer of ice for much of the past one million years. As the last ice ages progressed, glacial erosion in the Arctic became less efficient and steep alpine landscapes were preserved by glacial armour. The rock samples from the Svalbard summits, along with reported findings of older sediments in a fjord valley, show that this area experienced little glacial erosion in the Late Quaternary.

Quite the contrary. The previous landscape has been preserved, explains UNIS scientist Endre Før Gjermundsen, lead author of the paper.

"Our data show that these seemingly 'young and fresh', high-relief landscapes actually are conserved landscapes from long ago. A blanket of ice has protected the shape of the landscape and conserved a much older topography."

"BIPOLAR" BEHAVIOUR

The scientists propose that the ice covering the Svalbard summits switched from an erosive "warm-based" mode to a "cold-based" mode that conserved the landscape. The concept of cold- and warm-based ice has long been known to scientists; however, until now cold-based ice has mainly been coupled to low-relief upland surfaces lacking in alpine glacial shapes, says Gjermundsen.

The scientists spent several months out in the field in Svalbard.

Photo: Endre Før Gjermundsen, University Centre in Svalbard

"For the first time in the northern hemisphere we are able to show with the combination of the two isotopes that alpine mountains were protected from atmospheric weathering and glacial erosion for the majority of the last million years", says project leader Anne Hormes from the University of Gothenburg and UNIS.

Gjermundsen adds, "Our research shows that the glacial erosion processes are much more complex than we thought. It seems that the glaciers have exhibited a 'bipolar' behaviour, both as an erosive agent, but also as a conserving agent – even in the alpine areas we thought were most prone to erosion."

These new findings open up for more investigations in other areas with alpine landscape features, such as the Himalayas, sometimes called "the third pole".

Lead author Endre Før Gjermundsen sampling rocks on Jäderinfjellet in Svalbard.

Photo: Anne Hormes, University Centre in Svalbard

FURTHER READING:

Gjermundsen EF, Briner JP, Akçar N, Foros J, Kubik PW, Salvigsen O, Hormes A. (2015) Minimal erosion of Arctic alpine topography during the late Quaternary glaciations. *Nature Geoscience*. doi: 10.1038/ngeo2524

http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2524.html

Pedro Duarte // Norwegian Polar Institute

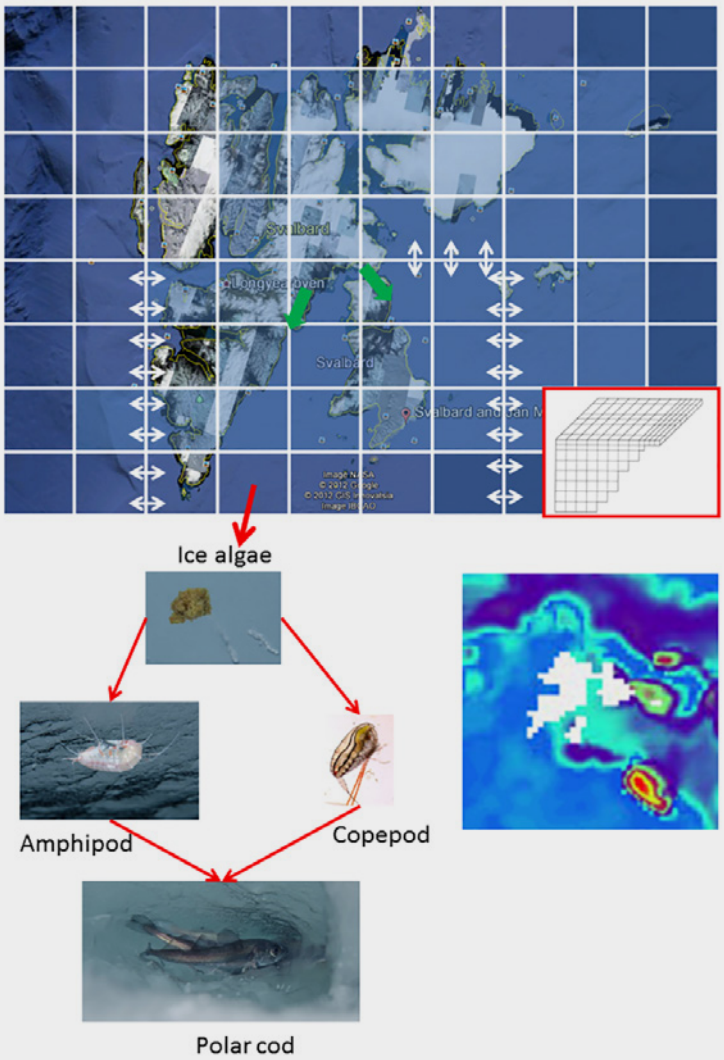
Modelling the ecosystem in the Arctic Ocean around Svalbard

Thick old sea ice in the Arctic Ocean is being replaced by thin new ice or open water, offering fresh opportunities for commerce at the top of the world. But what will happen to the organisms that live there now?

The Arctic Ocean is changing rapidly; it is growing warmer and less basic, and the sea ice is shrinking and getting thinner. Longer periods with less sea ice open up for economic activities such as oil exploitation, fisheries and shipping. But such activities increase the risks of contamination and overfishing, and might have negative effects on arctic organisms, ecosystems and societies. We also know that changes in the Arctic Ocean can have impact on climate and ecosystems far from the Arctic. This underscores how important it is to understand what causes these changes and to predict their consequences.

A wealth of information on biogeochemical processes has been gathered during field research like the recent Norwegian Polar Institute N-ICE[2015] project, when the research vessel *Lance* drifted with the sea ice north of Svalbard for six months. These data can tell us many things. But the interrelations between physical, chemical and biological processes are so complex that understanding how they cause changes is a gargantuan challenge.

One way to tackle this complexity is to use mathematical models. These represent the geographical areas under study as a grid. For each cell in the grid, the model takes the best available knowledge from various fields of science and makes detailed calculations in an attempt to forecast the evolution of physical, chemical and biological properties in sea water and



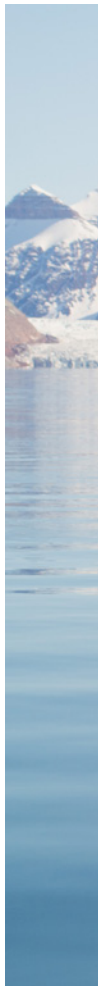
HOW THE MODEL WORKS

At the top we see a modelled region around the Svalbard archipelago. The vertical and horizontal lines show the type of grid the model uses (here simplified for legibility: the cells are much smaller in the model). The grid is three-dimensional, as shown in the red box to the right. The white and green arrows represent current velocities and directions the model must calculate in order to forecast how dissolved or suspended matter and plankton are transported in the water. The red arrows indicate that for each cell on the grid, the model calculates biological processes such as growth of the different organisms and their interactions, such as grazing. Model results can be plotted in maps like the one at the lower right, where different colours represent different concentrations or abundances. Series of maps like this one can be put together to create an animation showing how a modelled variable evolves over time and space.

Photos: Ice algae, amphipod, polar cod, Peter Leopold, Norwegian Polar Institute; copepod, Anette Wold, Norwegian Polar Institute

sea ice. Such effects can be closely intertwined. For example, the abundance of various types of plankton is central to these calculations, but depends not only on how the plankton use light, nutrients and other organisms, but also on how they are transported by ocean currents. That means the currents must also be calculated. Sea ice adds another level of complexity because it is not just an inert layer of frozen water but a "living ecosystem" that interacts with sea water and the atmosphere.

Constructing such a complex model is a huge task - but it can be facilitated by integrating and complementing already available models for some of the processes that must be simulated. We have used this approach in the Fram Centre Arctic Ocean flagship project "**Ecosystem modelling of the Arctic Ocean around Svalbard (ArktisMod)**". ArktisMod combines physical oceanographic and biogeochemical models to create a realistic representation of the Arctic marine ecosystem. The physical component of the model was developed within another Fram Centre project: **"Mesoscale modelling of ice, ocean and ecology of the Arctic Ocean"**. Once the models have been put together, model simulations can be used to analyse the effects of changing environmental conditions such as ice cover, water temperature and ocean acidification, on water properties and abundances of different organisms.



Maria E. Granberg and Geir Wing Gabrielsen // Norwegian Polar Institute

Impact of petroleum-related PAHs on arctic marine ecosystems

At COP21 in Paris, many countries agreed to cut CO_2 emissions and increase energy efficiency. Nonetheless, energy demand is expected to increase by 30% before 2040. If the petroleum resources in the Arctic are exploited, how might that affect arctic marine ecosystems?

OIL PRICES ARE FALLING and the oil industry is downsizing. Today 82% of the global energy use depends on fossil fuels while renewable resources comprise only 3%. The International Energy Agency and the International Association of Oil and Gas Producers (IOGP) both predict increased oil and gas production in the coming years to meet the growing energy demand. The Arctic holds 13% of the world's undiscovered recoverable oil and 30% of its natural gas, and is identified by IOGP as the next petroleum exploration and production area. This poses a dilemma.

Polycyclic aromatic hydrocarbons (PAH) are the most persistently toxic component of oil, coal and "produced water" (a by-product of petroleum production). PAH molecules have a core of aromatic rings to which other chemical groups can be attached. PAHs without attached groups are called parent PAHs, while those with attached hydrocarbon groups are called alkylated PAHs. Alkylated PAHs constitute 80-95% of the PAHs in crude oil, diesel, produced water and natural coal. Despite this fact, many countries, including Norway, use the United States Environmental Protection Agency's standard from 1976, which quantifies and considers only 16 parent PAHs. Similarly, the Norwegian Food Safety Authority considers just one to five parent PAHs when assessing the risks of human exposure through seafood. These government strategies have unintentionally directed scientific focus towards parent PAHs. Consequently, current knowledge on the environmental concentrations, toxicology and ecotoxicology of alkylated PAHs is very limited, and ecological and human PAH exposure may be underestimated.

Vertebrates metabolise and eliminate parent PAHs. This means that the chemicals do not biomagnify (i.e. increase in concentration along food chains) and are thus not considered a problem for higher organisms other than during events such as acute spills. Conversely, alkylated PAHs are known to bioaccumulate (i.e. be taken up by living organisms) more readily than their parent PAHs and were recently shown to biomagnify. Alkylated PAHs often occur at higher concentrations than their parent PAHs in contaminated sediments, waters and exposed organisms. Thus it appears that alkylated PAHs "behave" differently in nature and in ecosystems than parent PAHs. Alkylated, rather than parent PAHs have been pointed out as causing the chronic toxic effects observed in organisms from bacteria and mussels to fish and sea otters. Finally, alkylated PAHs persist longer in the marine environment due to slow microbial degradation. Persistence, high bioaccumulation and biomagnification potential as well as high toxicity make the alkylated

On the way to a sampling site in Kongsfjorden, Svalbard.

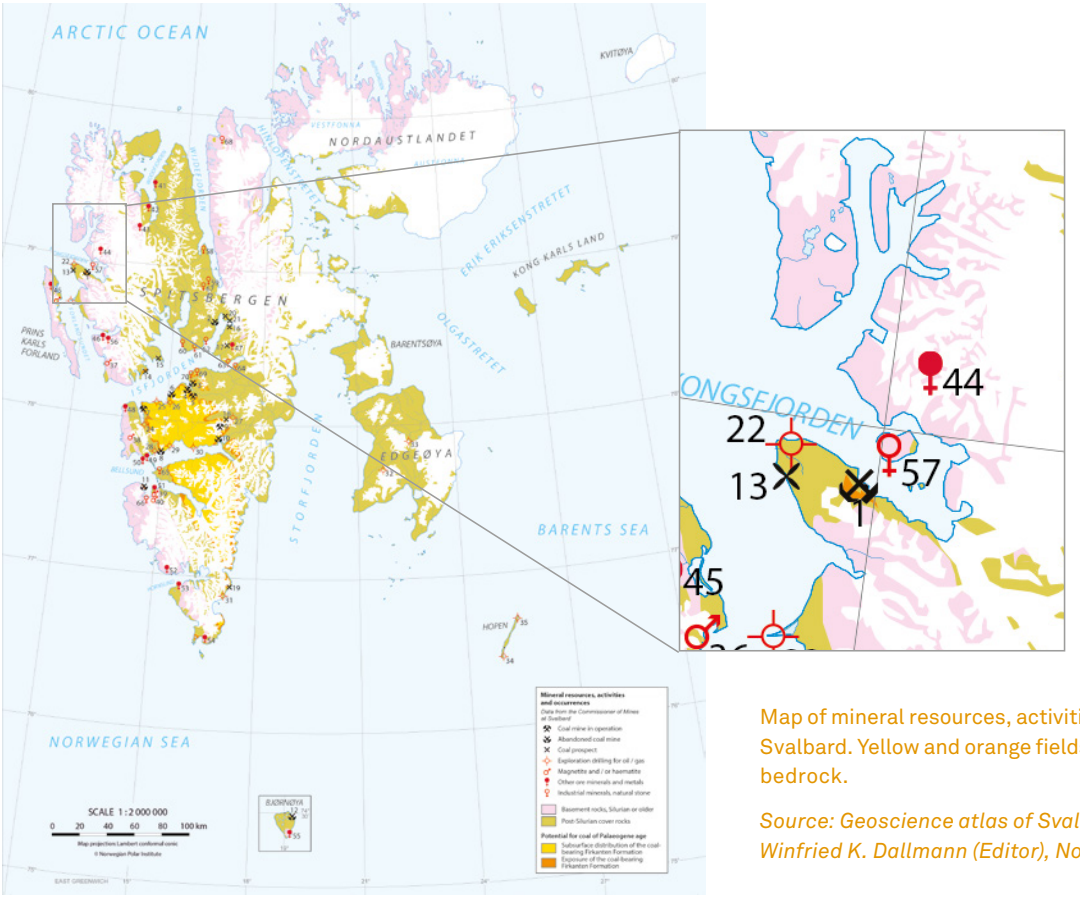
Photo: Kjetil Sagerup, Akvaplan-niva

Coal particles erode from bedrock and coal deposits and reach the intertidal sand and mudflats.

Photo: Maria Granberg, Norwegian Polar Institute

Marina Vazquez (MSc student) is rigging a trap for amphipods (small marine crustaceans), which will be analysed for PAHs and used in experiments. Kongsfjorden, Svalbard.

Photo: Ketil Hylland, Norwegian Polar Institute



Map of mineral resources, activities and occurrences on Svalbard. Yellow and orange fields indicate coal-bearing bedrock.

Source: Geoscience atlas of Svalbard, Winfried K. Dallmann (Editor), Norwegian Polar Institute

PAHs suspects for the chronic effects seen on marine organisms after accidental oil spills.

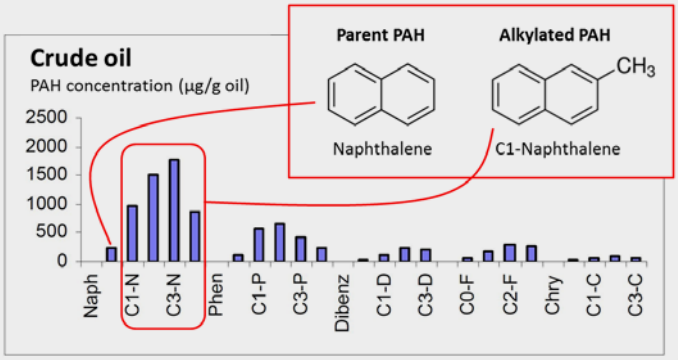
PAH IN SVALBARD

PAH concentrations in Norwegian arctic marine environments are generally low. However, parts of the Svalbard bedrock contain coal deposits. Natural and man-made erosion (mining) lead to continuous accumulation of coal particles in adjacent coastal sediments, resulting in local PAH concentrations comparable to those found in European harbor sediments. In coal, as in crude oil, alkylated PAHs predominate. PAHs bind strongly to coal particles, so their bioavailability may be fairly low. Still, the environmental impact of PAHs associated with native unburnt coal is unexplored.

Current knowledge on the fate and effects of PAH in the Arctic mainly concerns acute effects of parent PAHs after experimental exposure. We know very little about the effects of chronic exposure and the adaptive capabilities of living organisms, although these are much more relevant. Studies done after the Exxon Valdez accident in Alaska provided important ecotoxicological insight relevant for northern and arctic waters. However, the conclusions are obscured by the lack of data on pre-spill PAH concentrations and chronic toxicity, by disputes over experimental designs, and conflicts of interest. One thing we know for certain: some of the biological effects persist 25 years after the spill.

RESEARCH ON ALKYLATED PAHS IN SVALBARD

During two summer field seasons (2014 and 2015) a consortium of scientists from Fram Centre, Norwegian and international institutions have investigated the fate and effects of alkylated PAHs and PAH metabolites in the arctic marine environment. The overall aims have been to establish background levels and obtain refined fingerprints of PAHs (parent, alkylated and metabolites) along short arctic and boreal marine food chains, to link concentrations to physiological and genetic toxicity, and to determine the bioavailability of alkylated PAHs in coal-laden arctic sediments. Samples were collected from sediments, waters and invertebrates in Kongsfjorden, Svalbard and Tromsø. Blood and eggs of common eiders and glaucous gulls were also sampled. The results will enable us to evaluate the bioaccumulation- and biomagnification potentials of alkylated PAHs, among other things.



Part of a standard PAH fingerprint of crude oil. Naph indicates the two-ringed PAH naphthalene, and C1 to C4 indicates the number of methyl groups attached to the alkylated forms of the specific PAH. Alkylated PAHs dominate the PAHs in crude oil.

Diagram: Maria Granberg, Norwegian Polar Institute

Preliminary results from Kongsfjorden show ten times higher concentrations of alkylated PAHs than of the 16 "standard" PAHs in sediments collected near shores with coal-bearing bedrock. The fingerprints clearly show that the PAHs originate from coal or oil - not from combustion, as was the case in Tromsø. In areas of Kongsfjorden dominated by other rock types and glacier runoff, concentrations of all PAHs were low, yet with the same fingerprint as in the coal-contaminated area. The potential environmental impact of this sedimentary coal is unknown since alkylated PAHs have never been assessed in biota here. Bottom-dwelling invertebrate communities thrive also in areas with visible coal contamination - areas where seabirds feed at low tide. We hope to determine whether these invertebrates have evolved to cope with high PAH concentrations or if the coal-associated PAHs are not bioavailable. Results will provide indications on whether alkylated PAHs may pose a threat to the health of seabirds foraging in these areas. Biogeochemical and ecological processes in the seabed largely determine subsequent food chain bioaccumulation and impact.

OUTLOOK

To predict the environmental impact of exposure to PAHs from oil, coal or combustion, research and environmental assessments need a more refined approach that includes the alkylated PAH compounds (not just 16 parent PAHs) and a qualitative analysis of PAH fingerprints. Ecologically relevant background data on PAH and alkylated PAH concentrations, degradation rates, formation of toxic metabolites and the coupling between PAH fate and effects, will be essential when predicting the impact of change in chronic PAH exposures and risks associated with oil spills in the future Arctic. This is particularly relevant now that the Norwegian Ministry of Petroleum and Energy has announced the 23rd licensing round for oil and gas prospecting, where 54 of the 57 blocks are in previously unexplored areas of the southeast Barents Sea region. The Arctic Monitoring and Assessment Programme and others predict a general increase in the intensity of shipping, mining and off-shore oil and gas exploitation in the Arctic in the wake of climate change and reduced ice cover. These industrial activities generate PAHs and will probably increase background concentrations. The risk of oil spills and platform blow-outs resulting in acute PAH contamination is also increased by intensified industrial presence. Clearly, solid independent research is needed to support governmental decision-making in contexts where healthy arctic marine ecosystems and oil exploration or other industrial activities are intended to coexist.

OUR COLLABORATORS:

Kjetil Sagerup, Akvaplan-niva
Svein Are Hanssen, Norwegian Institute for Nature Research
Jasmine Nahrgang, UiT The Arctic University of Norway
Åse Krøkje, Norwegian University of Science and Technology
Ketil Hylland, University of Oslo
Gerard Cornelissen, Norwegian Geotechnical Institute
Jan H. Christensen, University of Copenhagen, Denmark
Linus M.V. Malmquist, University of Copenhagen, Denmark

Virginie Ramasco and Kjell T. Nilssen // Institute of Marine Research

Rests more and eats less

New research shows that harbour seals spend a lot of time resting while in the water and eat less than previously estimated. The study confirmed previous knowledge that harbour seals prefer small fish over large ones, but their diet changes with season depending on what fish are available near the seals' resting sites on land.

Harbour seals hauling out on land.
Photo: Michael Poltermann, Institute of Marine Research

THE HARBOUR SEAL

The harbour seal is a non migratory species found all along the Norwegian coast. Adult animals grow up to approximately 150 cm in length and weigh around 80-100 kg. Life expectancy is about 35 years. The species reaches sexual maturity at 4-5 years of age and females have a pup every year. Birth occurs on land in late June, but the pups are able to swim from the very first day. Harbour seals regularly gather on land to rest in groups at relatively fixed locations, called haul out sites. These animals can move up to several hundreds of kilometres to feed. The Institute of Marine Research conducts annual surveys along the coast, and provides updated national population estimates for the harbour seal every five years. There are now around 7 600 animals along the Norwegian coast, the population in Porsangerfjord consists at present of around 200 animals.

HARBOUR SEALS ARE CONTROVERSIAL all along the Norwegian coast. Many fishermen see them as one of their main competitors, and some seal populations have been severely decimated through hunting. However, the assumption that the harbour seal is a direct competitor for local fish resources is not well founded. This coastal seal species actually does not eat much cod and salmon of commercially interesting size.

During the last ten to fifteen years, the impact of the harbour seal population in Porsangerfjord has been a hot topic in the local press. The coastal cod stock in this fjord fell drastically in the 1980s, probably as a result of multiple major invasions of harp seals from the Barents Sea between 1986 and 1988, but also due to overfishing. In many other north Norwegian fjords the cod stock recovered, but not in Porsangerfjord - and the local harbour seal population was accused of being responsible.

REMOTE SENSING

Against this backdrop, the Institute of Marine Research funded a PhD project, in collaboration with the University of Tromsø, to investigate the ecological role of the harbour seal population in Porsangerfjord. Fifteen harbour seals were equipped with tracking tags (see fact box) that were able to determine the seals' position and register their dive pattern. At the same time, the fish resources in the fjord were surveyed by research vessels with standard methodology for acoustical measurements (echo sounder and trawl hauls). By combining these two types of data, we could study the animals' feeding behaviour in detail and relate it to the availability of potential prey in the area. The work was part of a larger project aimed to identify the most important ecological relationships between the marine species in Porsangerfjord (EPIGRAPH).

RESTING AT SEA

We already knew that harbour seals haul out on land to rest, but this study revealed that they also rest while at sea. We observed two different resting behaviours: floating for extended periods at the surface, and resting while diving. The animals slowly sink down in the water column due to their negative buoyancy, and then swim back to the surface to breathe. This behaviour has previously been described in other seal species, such as elephant seals, but not in harbour seals. The fact that they spend a significant amount of time resting in the water implies that harbour seals are less active than previously believed: their energy requirements and food intake are lower than the estimates obtained when it was assumed that they spent all their time in the water actively foraging.

SEASONAL SHIFTS IN PREY PREFERENCE

The transmitter tags gave insight not only on the seals' activity budgets, but also on how they feed. We inves-

A sedated harbour seal being tagged at the field station in Porsangerfjord. The tag is glued to the fur on the animal's back.

Photo: Michael Poltermann, Institute of Marine Research

tigated the choice of potential fish prey in relation to their availability in the Porsangerfjord. The availability of prey depends both on how close the fish are to the haul out sites where the seals start their foraging trips, and whether the foraging areas are accessible at all. In Porsangerfjord, for example, much of the seals' feeding grounds in the inner parts of the fjord are covered by sea ice in late winter and early spring, and the fish below are inaccessible for a breathing predator. We investigated prey density by means of boat-based sonar and seabed samples, which showed the distribution and abundance of herring, capelin, small and large codfishes and sculpins.

Both the results on prey preference and additional analyses indicated that harbour seals eat small fish (5-25 cm). Eighteen different species were found in the autumn diet. More than 50% were sculpins, while cod, saithe and haddock constituted about 30%. The results based on the seals' selection of feeding areas indicated that harbour seals in Porsangerfjord prefer small codfish species (under 25 cm) in autumn. In early winter, their preference shifts to small pelagic fish such as capelin and herring. These species gather in dense concentrations in the inner parts of Porsangerfjord to overwinter in cold, deep waters. When sea ice forms in late winter, these prey resources become unavailable for harbour seals, and their preference shifts to small codfish. When the ice melts in spring, harbour seals gather in the inner fjord again to feed on herring and capelin.

The results suggest that harbour seals prefer small pelagic fish when available in high densities and near their resting places. The seals' impact on small cod in Porsangerfjord will therefore change across seasons and years depending on the availability of highly concentrated small pelagic fish. We saw no evidence that harbour seals visit spawning areas for large cod further out in the fjord. Nor did we see any behaviour that suggested particular interest in salmonids.

SIMILAR FINDINGS ALONG NORWAY'S COAST

Our results are consistent with previous studies of harbour seal diet along the Norwegian coast. In Vesterålen, small saithe (5-30 cm) dominated the harbour seals' diet, which also included herring, sandeel, and small individuals of flounder and cod. In Froan, Sør-Trøndelag, small codfish, pout and pollack (<30 cm) were most important. Near Hvaler in Østfold, the diet consisted of 18 species, mainly Norway pout. Herring, sandeels, sprat, blue whiting, whiting and saithe were also on the menu, while cod was almost absent. In the inner parts of Sognefjord, small haddock, pollock, cod, herring, sprat and smelt were most important; salmonids were absent from the harbour seal diet.

In summary, harbour seals are opportunists and eat what is most accessible among small fish species or small size-classes of larger species. They prey on small codfish, but prefer schooling fish (e.g. herring, capelin, sandeel and sprat) when available in high densities and at short travelling distances. Seasonal shifts in diet have been documented also in other systems outside of Norway. No data from Norwegian waters suggest that harbour seals are a major consumer of cod or salmon of commercially interesting sizes.

The tagged harbour seal is released from the shore. The tag will fall off at the next moult.

Photo: Michael Poltermann, Institute of Marine Research

THE TECHNOLOGY BEHIND THE STUDY

The tags used in this study (Sea Mammal Research Unit, St. Andrews, UK) were glued to the fur on the seals' back right after moult, giving a potential tagging duration of 11 months, until next moult, when the tag would be lost. Equipped with various sensors, the tags were programmed to register different types of data at regular intervals. The data were encoded in regular text message formats and sent to the researchers via the mobile phone network.

The tag and its sensors.

Photo: Michael Poltermann, Institute of Marine Research

FURTHER READING

PhD thesis by lead author Virginie Ramasco: http://munin.uit.no/handle/10037/8149

More on harbour seals: http://www.imr.no/temasider/sjopattedyr/sel/steinkobbe/en

More on EPIGRAPH: http://www.imr.no/epigraph

Øyvind Stokke // UiT The Arctic University of Norway

Climate matters at the Department of Philosophy!

Climate ethics is a new area of priority at the Department of Philosophy at UiT The Arctic University of Norway, reflecting the university's overall research strategy – and the project *A new climate ethic for the Arctic* (ACEA) was present at COP 21 in Paris!

One of the side events at the COP21 meeting was an Arctic Climate Research Strategy Meeting. This is a joint effort to launch a Nordic-led research consortium and identify future interesting Arctic climate research questions within the humanities and social sciences. The consortium agreed on a proposal concerning transnational knowledge relations and science diplomacy in the Arctic.

The interdisciplinary approach of ACEA has resulted in collaboration between researchers at UiT, the Norwegian Polar Institute, K.G. Jebsen Centre for the Law of the Sea (JCLOS), Stockholm University, the Chilean Antarctic Institute (INACH), and the University of Akureyri (Iceland) to mention a few. Within the cross-disciplinary research project "Sustainable energy production and CO_2 sequestration by mass cultivation of growth efficient northern and arctic diatoms (ECO)", ACEA is responsible for WP6 devoted to testing the twin assumptions that

1) Norway could take parts of its fair share of a global mitigation scheme through *local* carbon capture and storage, and production of biofuel from terrestrial sources in large scale, and

2) Climate engineering is sustainable from the point of view of climate justice.

These two assumptions reflect another, more fundamental assumption of the ACEA project: Just distribution of emission shares must be integrated into a wider theory of climate justice that takes into account differential *needs*, access to *alternative energy sources*, other mitigation, adaptation and compensation *duties*, and *historical responsibility*. For example, it takes seriously the fact that about four hundred thousand indigenous people are already experiencing the effects of global climate change. Many of them live traditional lives, hunting and herding reindeer, *and have contributed virtually nothing to climate change*. For that very reason, their life forms and knowledge are of vital importance in our search for an ethic of climate governance in the Arctic.

In 2014, a research proposal on Arctic climate justice received funding from UiT, and in 2015 Kristoffer Mällberg started his PhD project *Protecting cultural practices from climate change*. Mällberg focuses on adaptation, asking whether liberal nation states have a duty to protect existing ways of life from external influences such as global climate change; what the basis

The author (left), postdoc Aaron Maltais (right, Stockholm University). Between them, participating by Skype from Stanford, is Megan Blomfield, who stayed awake for two nights (California time) listening to and commenting on presentations.

Photo: Tim Dassler, UiT The Arctic University of Norway

of such a duty might be, and what it would demand. Both Stokke and Mällberg were included in the science session "Arctic climate change - global implications" at the Arctic Frontiers conference held in 2015. ACEA is also an active part of the current initiative to establish a Research Centre for Energy, Climate and Society at UiT.

As part of the research group *Pluralism, democracy and justice* we organized two international conferences in June 2015. *Climate change - political and ethical strategies* hosted some of the most outstanding speakers within the climate justice and environmental ethics debate. They discussed whether an action (or inaction) on the part of states and large corporations that poses a risk of human extinction should be deemed an international crime, what kinds of agents are fit to be assigned remedial responsibility for climate change, and what agents should do when others fail to comply with their duties to remedy climate change. An edited volume of conference proceedings being considered for publication by Rowman & Littlefield Int.

The other conference, entitled *The role of Norway, Chile and Argentina as Original Claimants and Current Guardians of Peace, Science and Environmental Protection in Antarctica*, co-organised with Alejandra Mancilla at INACH, gathered a consortium of researchers from philosophy, law, anthropology and environmental management. This conference resulted in the research proposal *From sovereignty to stewardship: Current challenges and future possibilities for sustainable environmental governance in Antarctica*, a project that will be directed by ACEA.

Antarctica, our fifth largest continent, is one of the four global commons recognised by international law, and is considered as "the world's last store of natural resources". Today, environmental protection in Antarctica is under pressure. New actors and activi-

From the workshop "The role of Norway, Chile and Argentina as Original Claimants and Current Guardians of Peace, Science and Environmental Protection in Antarctica" funded by the Norwegian Latin America Research Network (NorLARNet). Participants, left to right, Gustavo Ramírez (Universidad de Magallanes, Chile), Kristin Tilli (Masters student at the Faculty of Law, University of Akureyri, Iceland), postdoc and organiser Alejandra Mancilla (Centre for the Study of Mind in Nature/UiO and INACH), associate professor and organiser Øyvind Stokke (UiT The Arctic University of Norway), associate professor Espen Gamlund (University of Bergen), and associate professor Steve Vanderheiden (University of Colorado, USA).

Post-doc and organiser Alejandra Mancilla.

Both photos: Ágúst Þór Árnason, University of Akureyri

ties; ecological and environmental challenges like the steep increase in tourism; illegal, unreported, and unregulated (IUU) fishing; climate change; the increasing presence of plastic pollution in the Southern Ocean; and the cumulative impact of human settlements in the Antarctic environment: all these developments are testing the governance capabilities of the Antarctic Treaty System. However, its decisions are binding to its members only. Our aim is, first, to examine the existing legal instruments that the Antarctic Treaty System currently has at its disposal to achieve environmental sustainability in Antarctica. Second, we expound and develop two legal instruments - *Comprehensive Antarctic Regime of Environmental Liability* and *Antarctic Environmental Fund* – both designed for the protection and restoration of the Antarctic commons.

In March, *The Ethics Group* at our Department organised the workshop *Anthropocene - ethical, biological and philosophical perspectives*. "The Anthropocene" is the proposed geological term referring to the epoch in which human impacts on the earth's ecosystem are dominant, and presenters from a wide range of disciplines raised important questions about how we humans should respond to our impact and about our responsibility for the earth's ecological systems. Associate professor Svein A. Lie directs the environmental ethics research initiative in this group. Lie has published widely within this area, including *Philosophy of Nature: Rethinking naturalness* which just appeared in the Routledge Explorations in Environmental Studies series.

I had the honour of rounding off the University's Saturday lecture series with a talk entitled "What is climate justice?"

NAMES IN THE NEWS

NEW DIRECTOR AT CLIC

Lawrence Hislop was appointed Director of the Climate and Cryosphere Project (CliC) in December 2015. He succeeds Jenny Baeseman, who has taken up the post of Executive Director of the Scientific Committee on Antarctic Research.

Hislop is from Montreal, Canada and has more than ten years' international experience of leading projects funded by the United Nations and the European Union. He has produced many environmental assessments and related communication products. CliC has offices at the Norwegian Polar Institute in Tromsø.

NEW DIRECTOR OF THE INSTITUTE OF MARINE RESEARCH

In October 2015, the Norwegian government appointed Professor Sissel Rogne as Director of the Institute of Marine Research. She succeeded Tore Nepstad in the post.

Sissel Rogne was previously Director of the Norwegian Biotechnology Advisory Board and part-time professor at the University of Bergen and the Norwegian University of Life Sciences (NMBU). She trained as a cell biologist, obtaining a PhD from the Faculty of Medicine at the University of Oslo, and has held a number of different research and leadership positions, including Director of Research at NMBU.

CHANGE OF THE GUARD AT UNIS

In February 2016, Ole Arve Misund took up his new post as Director of the National Institute of Nutrition and Seafood Research. Misund had previously been Director of the University Centre in Svalbard (UNIS) since March 2012. As Fram Forum goes to press, it is not yet clear who will take over as head of UNIS in Longyearbyen.

NEW LEADERS AT THE FRAM CENTRE

Anne Husebekk, Rector at UiT The Arctic University of Norway, took over as leader of the Fram Centre in February 2015. She was elected by the Committee of Institutional Directors, the Fram Centre's highest governing body.

Anne Husebekk succeeds Jan-Gunnar Winther. Winther, who is Director of the Norwegian Polar Institute, has been leader of the Polar Environment Centre since 2007 and continued as leader of the Fram Centre when it was officially opened on 29 September 2010. The office of leader is important in the work of framing and pursuing the Fram Centre's strategies in scientific research, management and outreach activities.

Anita Evenset, Director of Research at Akvaplan-niva, took over in March 2015 as leader of the Fram Centre's research leaders' group. She succeeded Sidsel Grønvik, Director of Research at the Norwegian Institute for Nature Research.

Laura de Steur, Paul A. Dodd, Sebastian Gerland, Mats Granskog and Agneta Fransson
// Norwegian Polar Institute
Gunnar Spreen // University of Bremen, Germany
Melissa Chierici // Institute of Marine Research
Colin Stedmon // Technical University of Denmark

Highlights from the Fram Strait Arctic Outflow Observatory

Fram Strait is the main gateway for exchange of sea ice, freshwater and heat between the Arctic Ocean and the North Atlantic. For nearly two decades we have monitored these exchanges, hoping to understand the ongoing changes in the Arctic Ocean. Here are some of our most interesting findings so far.

FRESHWATER, SEA ICE AND ATLANTIC WATER

The freshwater content in the Arctic Ocean increased significantly during the 2000s. Up to 2010, our time series of freshwater export through Fram Strait showed no corresponding increase. This may be because freshwater continued to accumulate in the Arctic Ocean to be released at some point in the future. Observations collected between 2010 and 2015 are currently being analysed at the Norwegian Polar Institute to see if freshwater outflow has increased in recent years. We are also integrating novel observations obtained from instruments closer to the surface, improving our ability to detect variations in the outflow.

Almost 90% of all sea ice export from the Arctic Ocean takes place through Fram Strait. Sea ice makes up about half the total freshwater outflow there. Moored, upward-looking sonars in Fram Strait have monitored sea ice thickness continuously since 1990. The measurements revealed that both thick, deformed, multi-year sea ice and level ice decreased in thickness by nearly half a metre per decade. Hence, the thickness of multi-year flat sea ice in Fram Strait is currently only 2 m, as opposed to 3 m in the 1990s.

Our time series also indicate that half of the warm Atlantic Water that flows towards the Arctic Ocean takes a short cut and recirculates in Fram Strait. This salty, “heavy” water contributes to the dense overflows further south that drive large scale circulation in the Atlantic Ocean. Monitoring the temperature of the Atlantic Water is also highly relevant because of its potential impact on the Greenland ice sheet: a warmer ocean might speed up the movement of calving glaciers in eastern Greenland.

FRESHWATER SOURCES AND SEAWATER PROPERTIES

The natural biogeochemical composition of water samples collected in Fram Strait has been measured annually since 2008. These data allow us to identify different sources of freshwater: run-off, precipitation, sea ice meltwater and freshwater from the Pacific. Run-off (mostly from Siberian rivers) consistently contributes most freshwater to the East Greenland Current. Occasionally, large pulses of freshwater from the Pacific are observed in Fram Strait. These pulses imply a temporary change in the Arctic Ocean circulation in the years before, most likely driven by changes in large-scale atmospheric circulation. The high freshwater content in the outflow water results in very low pH.

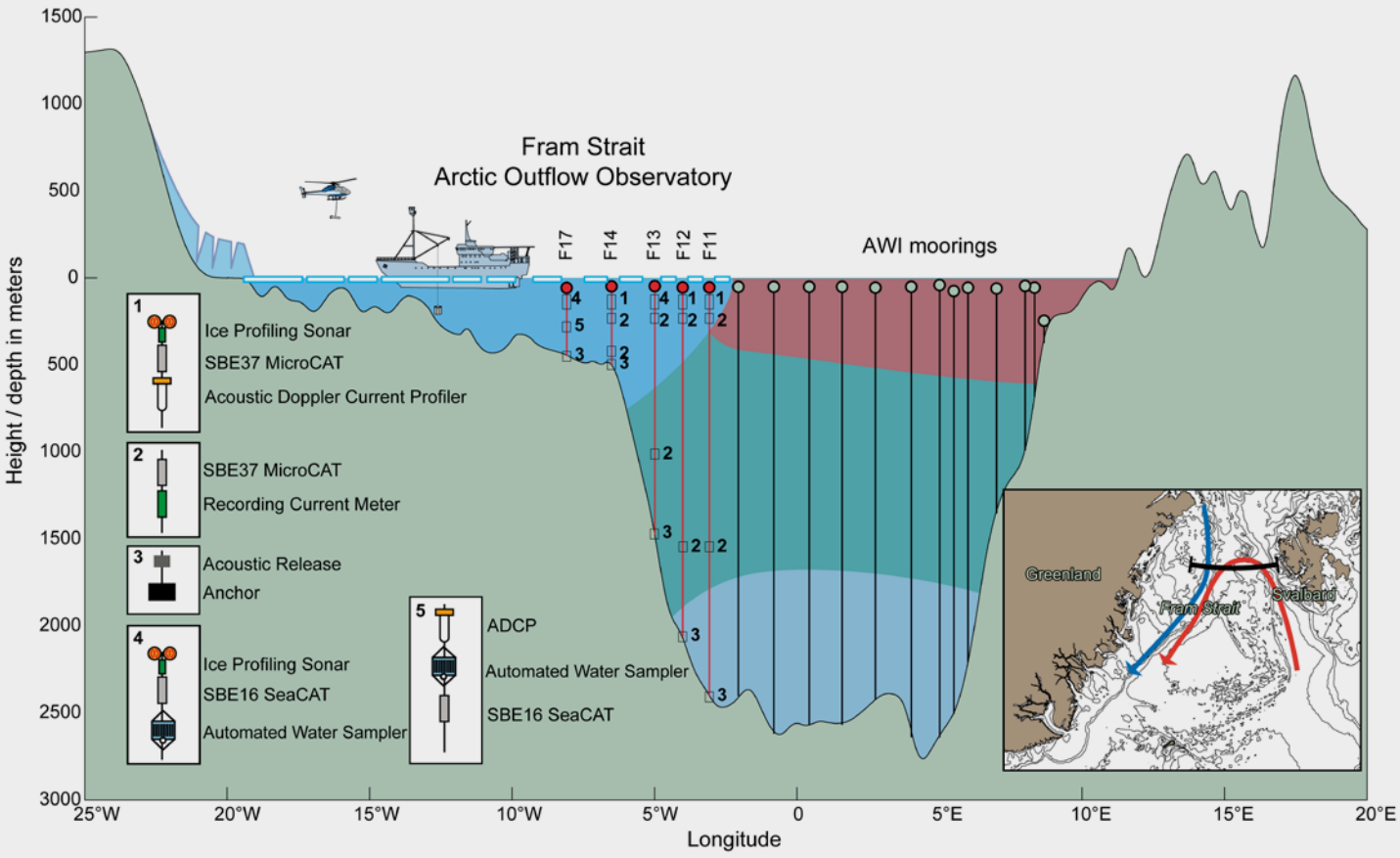
Recent observations of the carbonate system (total inorganic carbon, pH, alkalinity, CO_2 content) in Fram Strait give basic information about acidification state in the Arctic Ocean. Organic carbon (largely originating from Siberian rivers) can be used to distinguish additional sources of freshwater, and when combined with observations of the carbonate system and ocean acidification state, can help us figure out how much meltwater from the Greenland ice sheet enters the ocean in western Fram Strait.

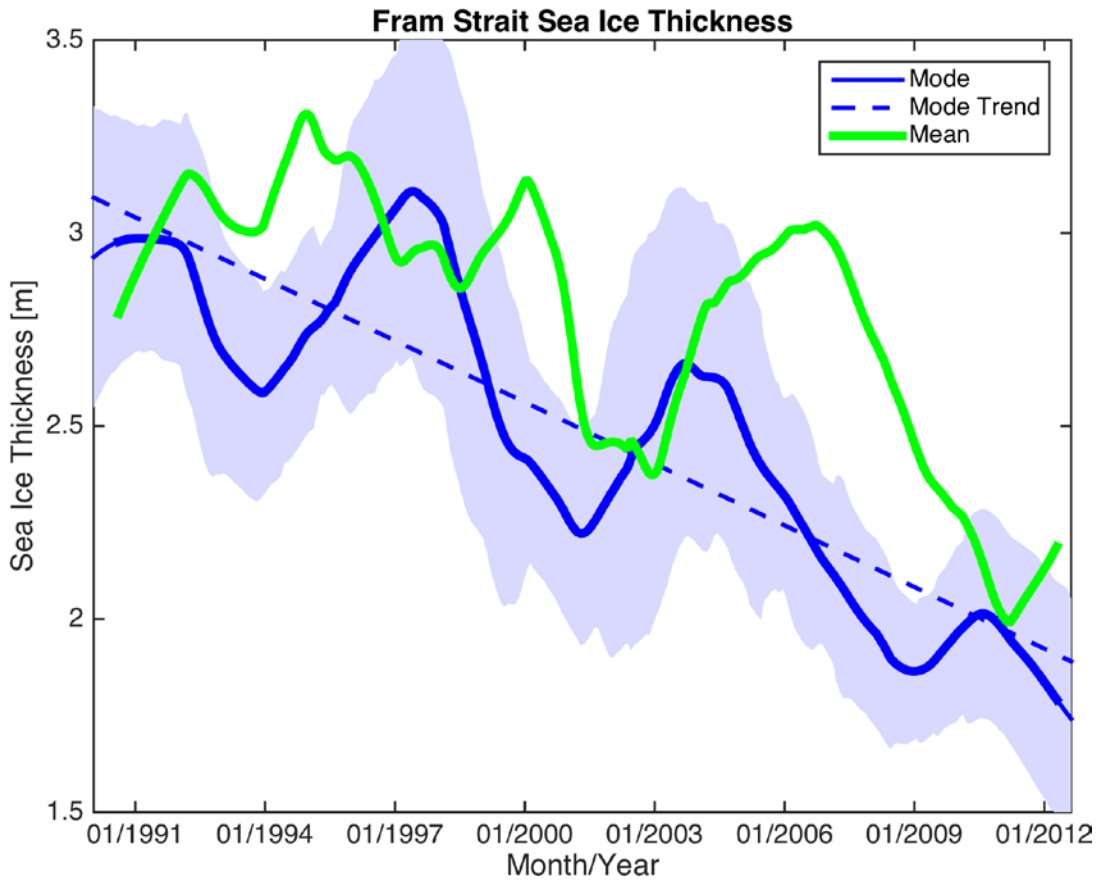
FURTHER READING

http://www.npolar.no/framstrait

The Fram Strait Arctic Outflow Observatory is a regional observing system – an array of moorings – at 78°50'N between Svalbard and Greenland. It provides long-term, continuous observations of the ocean (temperature, salinity, current velocity) and sea ice (thickness and drift velocity). When the moorings are serviced every year in September, we make additional detailed measurements of water flow and take samples of water and sea ice to measure various water characteristics. The diagram below shows the Norwegian Polar Institute's moorings (F11-F17) in the southward flowing East Greenland Current (light blue in profile; blue arrow in inset map) and moorings run by the Alfred Wegener Institute (AWI) in the West Spitsbergen Current and recirculation area (red in profile; red arrow in inset map).

Graphics: Audun Igesund, Norwegian Polar Institute





Data from mooring F13 show decreasing thickness of ice leaving the Arctic Ocean through Fram Strait. The blue line (Mode) shows the thickness of the most common ice type; the green line (Mean) shows the average thickness of all ice, including new ice, old ice and deformed ice such as pressure ridges.

Graph: Gunnar Spreen, University of Bremen

A mooring equipped with instruments ready to be deployed in the East Greenland Current for another year. The floats keep the mooring upright in the water column while a heavy anchor keeps it at the bottom. A sound-triggered mechanism will release the mooring from its anchor so it can be retrieved next year.

Photo: Paul A. Dodd, Norwegian Polar Institute

Maria Fossheim, Edda Johannesen and Randi B. Ingvaldsen // Institute of Marine Research
Susanne Kortsch, Michaela M. Aschan and Raul Primicerio // UiT The Arctic University of Norway
Andrey V. Dolgov // Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, Russia

Climate change is pushing boreal fish northwards

When the climate gets warmer, populations tend to shift poleward. This is now happening in the Arctic: fish species that prefer warm water are venturing north from the Atlantic and Pacific oceans. Here we present the case of the Barents Sea – the gateway from the Atlantic to the Arctic Ocean.

THE BARENTS SEA IS WARMING

The sub-arctic Barents Sea started warming in the late 1990s; bottom temperatures in late summer have increased almost 1°C during the last decade alone. Sea ice in this region is retreating and sub-zero water masses in late summer have almost disappeared. In association with this warming, boreal fish species are moving into the northern parts of the Barents Sea. This has led to a community-wide shift in fish composition in this region. The local Arctic community, which prefers cold water, has almost been pushed out of the shelf area.

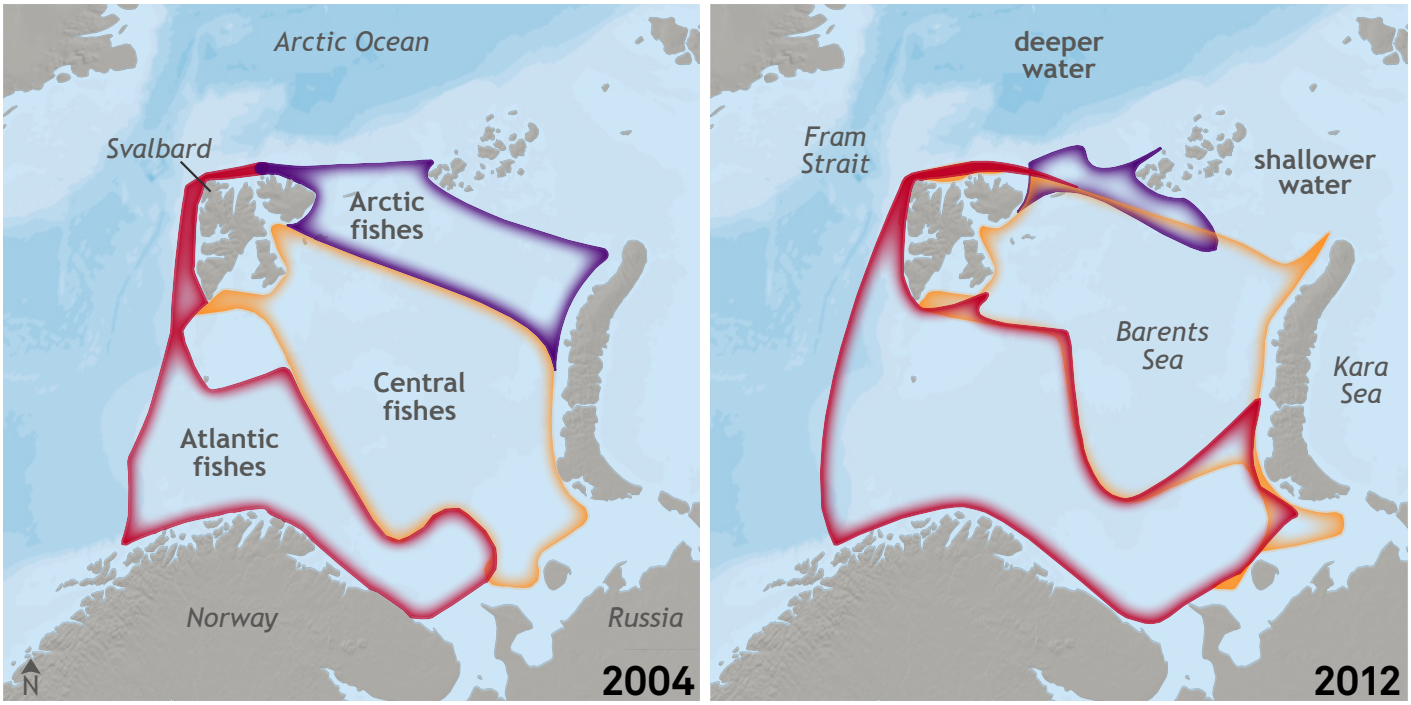
The fish increasing in the north are large predators, such as cod, beaked redfish and long rough dab. Improved habitat conditions (warmer water and more food) in the northern Barents Sea may explain the growing abundance of these species. The northward expansion of temperatures suitable for boreal species, increased productivity in a previously ice-covered area, and the increasing abundance and biomass of atlantic zooplankton in the northern Barents Sea, likely favour boreal over arctic fish species.

Cod, the commercially most important species, has reached a record high population size due to a favourable climate and lower fishing pressure. The cod stock in the Barents Sea has not been this high since the 1950s. The abundance of the other main commercial species - haddock - and of long rough dab has also increased recently. Other studies have suggested a poleward expansion of cod and haddock and a north-eastward displacement of beaked redfish, and our results confirm these trends.

IMPACT ON ARCTIC COMMUNITY SPECIES

The arctic fish community, including various snailfishes, sculpins and eel pouts, does not seem to cope well with rising seawater temperatures. Most of these fish species are relatively small and stationary and feed at the sea bottom. The main energy pathways in shallow arctic seas have been predicted to shift from seabed to water column as sea ice retreats - which is bad news for bottom-feeding arctic fish. These species have a more specialised diet than the boreal fish, and are thus more vulnerable to climate change. In addition, they are adapted to life on the shallow shelf of the

ARCTIC FISHES ALMOST PUSHED OUT OF THE BARENTS SEA BETWEEN 2004 AND 2012

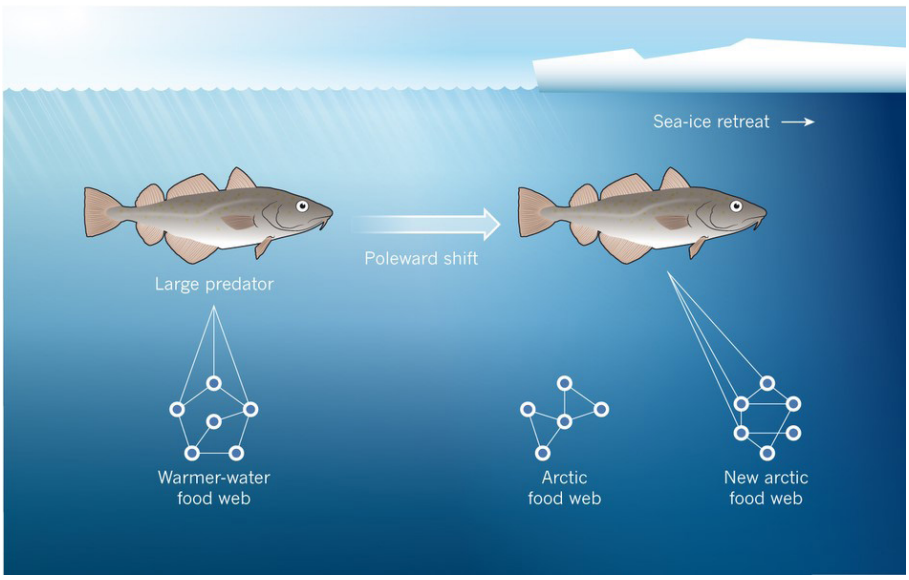


NOAA Climate.gov

Comparison of the fish communities observed in the Ecosystem Survey done in 2004 (left) and the survey from 2012 (right) indicates a significant change in distribution. The Atlantic (red) and central (orange) communities (boreal fish species) have shifted north and east, taking over areas previously occupied by the arctic (purple) community (arctic fish species). No data are available for the area northeast of Bjørnøya (Bear Island) in 2004.

Maps courtesy of NOAA Climate.gov

Arctic marine food web structure is changing due to poleward movement of boreal fish into the northeastern Barents Sea. The presence of cod and other large generalists in the arctic food web region introduces new feeding links. As these generalists feed on a wide range of prey from various habitats, their presence increases the connectance and decreases the modularity of the new arctic food web. This may have consequences for the way perturbations spread, but also enhance the transfer of energy and matter between the benthic and pelagic compartments of the new arctic marine ecosystem.



Reproduced, with permission, from Nature. Blanchard et al. (2015) Climate change: a rewired food web. Nature 527, 173–174 doi:10.1038/nature16311

Barents Sea. The Arctic Ocean is much deeper, so it is unlikely that these species can move further north, though they might conceivably move eastward into the neighbouring Kara shelf sea.

Large fish and marine mammals can move quickly over large distances, while small fish species and other organisms associated with the sea bottom are more stationary. As a result, two previously separate communities are now mixing together. The larger boreal fish species from the south will compete with the smaller arctic species for food, and even prey on them directly. This puts the arctic fish community under pressure from two sides: the marine environment is changing due to rising water temperatures, and they must contend with new competitors and predators. This could result in the local extinction of some arctic fish species, such as the gelatinous snailfish and even the most abundant arctic species, the polar cod, which has recently been added to the red list.

A NEW ARCTIC ECOSYSTEM

One consequence of large boreal fish generalists moving into the Arctic is novel feeding links between incoming and resident species, ultimately changing the structure of the arctic marine food web. Arctic food webs contain fewer connections than boreal food webs. This gives them some resilience, as the effects of perturbations may be restricted to few species. Conversely, Atlantic marine food webs contain many more connections, primarily due to large and wide-roaming fish species that feed on various types of organisms from many different habitats. These very same species are now moving into arctic waters, increasing the connectivity of the more simple arctic food webs. As the new arctic food web grows more similar to the relatively complex, interconnected boreal food web, it may also become more susceptible to perturbations. We also expect faster transfer of energy and matter between the seabed and the water column compartments in the arctic marine ecosystem. With increasing human activities in the Arctic, such as fisheries, oil exploration and shipping, a multitude of stressors will be acting on the communities in the Barents Sea. We must ask ourselves: How vulnerable are the new arctic food webs to the combined effects of climate change and human activities in the Arctic?

FURTHER READING:

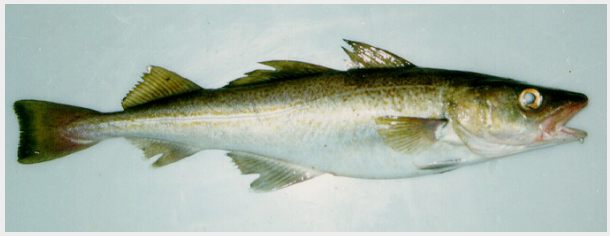
Fossheim M, Primicerio R, Johannesen E, Ingvaldsen RB, Aschan MM, Dolgov AV. (2015) Recent warming leads to a rapid borealization of fish communities in the Arctic. *Nature Clim. Change*, 5, 673-678

Kortsch S, Primicerio R, Fossheim M, Dolgov AV, Aschan M. (2015) Climate change alters the structure of arctic marine food webs due to poleward shifts of boreal generalists. *Proc. R. Soc. B*, 282. doi: 10.1098/rspb.2015.1546

Our results are based on an annual survey of the ecosystem in the entire ice-free shelf of the Barents Sea between August and September, when sea ice coverage is at a minimum. The survey has been ongoing in collaboration between Russia (Knipovich Polar Research Institute of Marine Fisheries and Oceanography) and Norway (Institute of Marine Research) since 2004.

This article is a modified version of the essay “Climate change is pushing boreal fish northwards to the Arctic: the case of the Barents Sea” published in Arctic Report Card 2015. http://www.arctic.noaa.gov/reportcard

INCREASING FISH SPECIES
(IN THE NORTHERN BARENTS SEA)



Cod

Beaked redfish

Long rough dab

DECREASING FISH SPECIES
(IN THE NORTHERN BARENTS SEA)

Greenland halibut

Twohorn sculpin

Gelatinous snailfish

In the northern Barents Sea, the abundance of typical boreal species (cod – *Gadus morhua*, beaked redfish – *Sebastes mentella*, and long rough dab – *Hippoglossoides platessoides*) increased from 2004 to 2012, while northern and arctic species (Greenland halibut – *Reinhardtius hippoglossoides*, sculpins – e.g. *Icelus bicornis*, and snailfishes – e.g. *Liparis fabricii*) decreased in abundance.

Photos: Andrey Dolgov, PINRO

Geir Moholdt // Norwegian Polar Institute

Global glacier mass loss observed by satellites

You're in a field of snow and ice. With meticulous care, a warmly dressed person plants what appears to be a beanpole in the ice. He (or is it she?) writes a few numbers in a notebook, drives a snowmobile a couple hundred metres and plants another beanpole. You've just seen a glaciologist at work.

GLACIERS GENERALLY GROW by snowfall in the winter and shrink by surface melting in the summer. The difference between the two is called glacier mass balance, and is of great interest to glaciologists. Glacier mass balance can be determined in the field by measuring changes in the height and density of the surface layer at reference stakes - "beanpoles" - along the flowline of a glacier. This painstaking and laborious procedure provides excellent records of seasonal climate conditions; some of the glaciers near Ny-Ålesund have been monitored this way for almost 50 years.

But there are about 200 000 glaciers in the world. Less than 1% of them are being measured on site, and these are often small, easily accessible glaciers rather than large, remote ones such as those commonly found in the Arctic, the Himalayas and Patagonia. So how can we determine glacier mass balance on a global scale? How can we calculate its contribution to sea level rise?

The short answer is: satellites. Imaging satellites have been used for years to map glacier outlines and how they change over time, but changes in area and length cannot easily be converted to mass balance. By combining images from different viewing angles, one can generate 3D models of glaciers. If 3D models from different times are compared it is possible to derive volume changes and hence mass balance - provided one can assume ice density. But 3D modelling has not been done on a global scale, and even if it had, we would need to average measurements over many years to get reliable estimates. Therefore, the research development has shifted towards using new satellite techniques like repeat-pass gravimetry and high-resolution altimetry, available since the early 2000s.

SATELLITE ALTIMETRY

Satellite altimeters - altitude meters - use radar or laser ranging to profile the Earth's surface along pre-determined orbits. Profiles that are repeated can be compared to reveal changes in surface elevation with an accuracy of a few decimeters. By doing this over all glaciated areas, we can obtain a rather random sample of changes in glacier thickness. If we then extrapolate to unmeasured areas, we get an estimate of changes in volume and mass balance of the glaciers in an entire region. This strategy was first tested and validated at Austfonna ice cap in Svalbard and has since been applied to the major glacier regions of the world, first with laser altimetry data from NASA's ICESat mission (2003-2009) and now with data from ESA's CryoSat-2 mission (2011-present).

Setting up a measurement station with snow sensors for calibration and validation of CryoSat-2 on Austfonna ice cap, Svalbard.

Photo: Thorben Dunse, University of Oslo/Norwegian Polar Institute

SATELLITE GRAVIMETRY

Another new way of determining glacier mass changes at regional scale is by sensing their impact on the gravity field over time. GRACE is a twin-satellite constellation that uses a laser ranger to track the satellites' movement in relation to each other; this movement is a consequence of variations in Earth's gravity field over a scale of a few hundred kilometers. Glacier mass changes have a direct impact on the gravity field - along with other factors such as isostatic rebound, terrestrial water storage and seasonal snow. If these latter effects are known or negligible they can be deducted from the gravity anomaly, and whatever remains provides an estimate of regional glacier mass balance.

Estimates obtained for the major glacier regions of the world using altimetry and gravimetry agree well in both space and time. For the first time, we have high confidence in global estimates of glacier mass balance! And the results? All major glacier regions have experienced mass losses over the past decade, with largest total losses in Alaska and Arctic Canada. Taken together, the world's glaciers have lost about 260 gigatonnes of ice per year. This is of the same magnitude as the loss from the considerably larger ice sheets of Greenland and Antarctica, which contribute a substantial sea level rise of about 0.7 mm/year.

Careful measurements done using the "beanpole" method indicate that glacier mass losses have accelerated over the past few decades. The new results from satellites provide a benchmark for re-assessing these records and for validating atmosphere-glacier models that can predict future changes based on climate scenarios.

Magali Lucia, Maria E. Granberg and Geir W. Gabrielsen // Norwegian Polar Institute

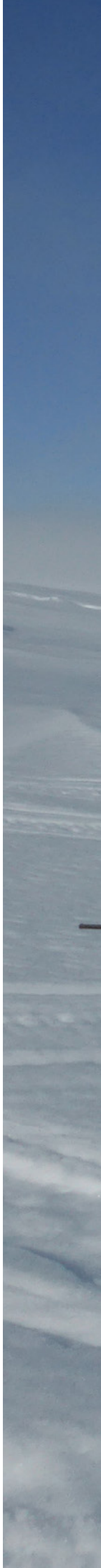
Pollutants in the Arctic: challenges for research and monitoring

The Arctic is under pressure from pollutants. Some of them come from local sources; others from far away. Many originate from human activities, but some are natural. Figuring out what impact pollutants will have on everything from individual plankton to entire ecosystems is a major challenge.

HUMAN IMPACT ON ARCTIC ECOSYSTEMS is complex: natural and anthropogenic factors interact to affect ecosystems at many different levels. Two major anthropogenic drivers in the Arctic are climate change and pollutants from both local and remote sources. Local pollution can be related to the lifestyle of people in small arctic communities, including past and present industrial activities. It can come from "natural" sources, through erosion or seepage from coal and oil deposits and metal-laden bedrock. Other pollutants come from far away. Chemicals produced and released in industrialised parts of the world are transported northwards by sea, air and water masses. This makes pollution in the Arctic a truly global problem.

These pollution pressures in the arctic ecosystem prompted the Norwegian Polar Institute to establish a series of programmes aimed at monitoring spatial and temporal trends in contaminant exposure of arctic biota. Since 1928, the Institute has conducted systematic surveys and scientific studies of polar regions on behalf of the Norwegian government. At present, the Institute is an important supplier of data for MOSJ (Environmental monitoring of Svalbard and Jan Mayen), an integral part of the Government's environmental monitoring in Norway. Researchers from the Norwegian Polar Institute collect and process data concerning factors with environmental impact, and about the status of the natural heritage of Svalbard and Jan Mayen. Seabirds, marine mammals, commercially exploited fish stocks, and zooplankton: all these are monitored. The objective of MOSJ is to improve knowledge about the protected areas in Svalbard, thus contributing towards improved management and protection of these vulnerable areas. An important task in MOSJ is therefore to monitor pollutants in arctic species.

The Norwegian Polar Institute also participates in the Arctic Monitoring and Assessment Programme (AMAP). AMAP was established in 1991 to monitor identified pollution risks and their impact on arctic ecosystems. Being involved in these programmes and making them successful is in itself an important challenge. Such monitoring activities require adequate human and logistical resources, as well as access to remote geographical areas and species. Difficult as they may be, monitoring programmes are essential, particularly in the context of a changing environment.



Ivory gull equipped with a tracking device.
Photo: Magali Lucia, Norwegian Polar Institute

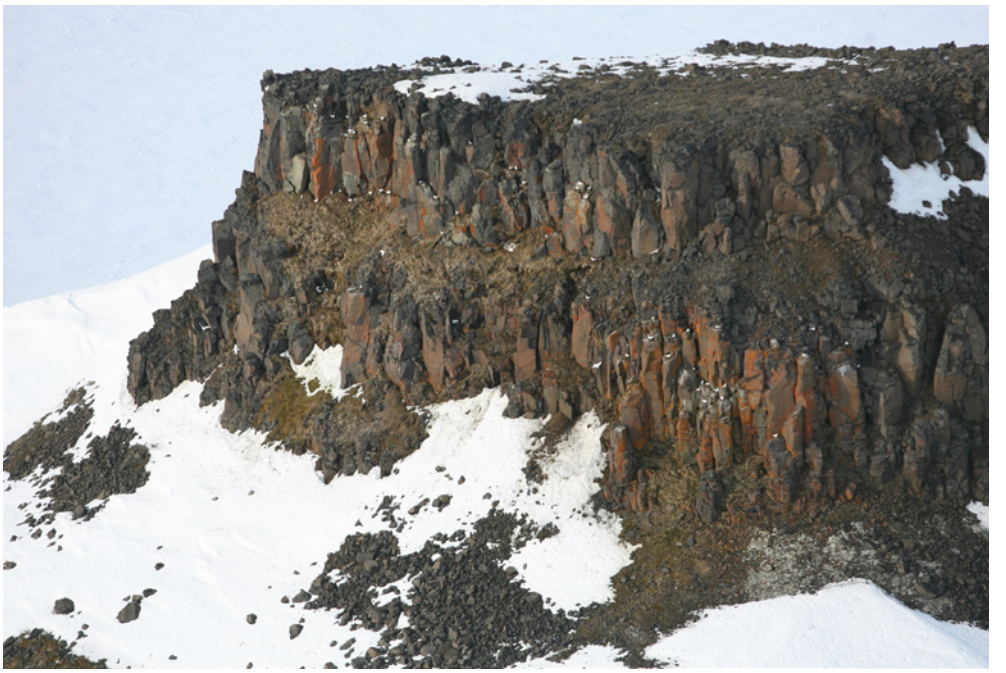
Census of ivory gull colonies in Svalbard.
Photo: Magali Lucia, Norwegian Polar Institute

One of the most important questions today regarding arctic pollution is how the levels, fate, and effects of pollutants will be affected by the changing climate. There is growing concern about possible changes in how pollutants are transferred to the Arctic, their partitioning and their fate within the ecosystem. These processes may change owing to higher temperatures, more low-pressure activity, increased river discharge and runoff from glaciers, as well as an accelerated rate of sea-ice melting. All these variables may influence the biodegradation and bioavailability of pollutants in the arctic ecosystem.

Climate change also affects living organisms directly, by modifying habitat structure, substrate and food availability and quality, in turn leading to changes in trophic interactions and ecosystem structure and function. One example is that climate change may alter prey communities in arctic waters, bringing more contaminated Atlantic prey into the Arctic. Contaminants are generally transferred from lower levels of food chains, such as invertebrates (mussels, gastropods, copepods) and fishes (polar cod and capelin), to higher levels, such as seabirds and polar bears. Changes in contaminant concentrations in prey species will affect the exposure of species at higher trophic levels. One of the challenges of predicting the effects of contaminants is therefore to identify changes in trophic interactions within arctic ecosystems.

Another fundamental and difficult challenge for monitoring studies is the constant emergence of new chemicals. Persistent organic pollutants (POPs) have been found in arctic species for decades. Concentrations of these “legacy” POPs have declined in the Arctic following bans and restrictions on use and emission in different parts of the world. However, new man-made chemicals constantly appear in the arctic ecosystem. Much research is therefore dedicated to developing or improving methods to identify and monitor the new chemicals we know exist - and screen for the ones we have not yet become aware of. In parallel, scientists are now trying to identify metabolites of pollutants, as these breakdown products can be highly toxic - sometimes even more so than the parent compound.

Thorough understanding of the state of the arctic environment also requires researchers to monitor far more than what may appear relevant for decision-making. In particular, it seems vital to provide knowledge about



Ivory gulls nest in inaccessible cliffs on nunataks far from the ocean.

Photo: Hallvard Strøm, Norwegian Polar Institute

how sensitive species that already live in a stressful environment will cope with long-term exposure to a cocktail of pollutants while simultaneously facing changes in their habitats (e.g. reduction of sea-ice cover). Effects in top predators, such as polar bear, arctic fox, glaucous gull, and great skua are well documented, and the Norwegian Polar Institute is currently involved in a project, funded by the European Union, to investigate the effects of pollutants on the vulnerable ivory gull. However, much of the true impact on biota of long-term exposure to a multitude of chemical stressors remains to be discovered. Moreover, it is difficult to extrapolate effects on individual organisms to the fitness of entire populations. Researchers therefore aim to merge findings from different scientific fields to draw a clearer picture of what impact contaminants may have on populations and ecosystems in the Arctic - now and in the future.

Researcher centrifuging blood.

Photo: Hallvard Strøm, Norwegian Polar Institute

Caixin Wang and Sebastian Gerland // Norwegian Polar Institute
Keguang Wang // Norwegian Meteorological Institute

Modelling upward ice growth on arctic sea ice

Sea ice normally grows downwards when new water molecules freeze to the bottom. But it can also grow upwards in the layer where snow and ice meet, substantially increasing total ice thickness. We need to learn more about this process and how it might affect the ice cover in the Arctic Ocean.

Sea ice covers about 12% of the world oceans and plays a key role in the global climate system and ecosystem. Sea ice is frozen seawater - not ice from glaciers - and is typically covered with snow for most of the year. If the snow is heavy enough to push the sea ice underwater, seawater floods the ice surface and overlying snow, forming a salty slush layer. When this slush layer freezes it forms what we call "snow ice". If rain falls onto snow-covered sea ice, or existing snow melts, the water seeps down to the original ice cover and forms a fresh (non-salty) slush layer. When this slush freezes the result is called "superimposed ice". Both these types of ice make the ice grow upward, contributing to the total ice mass and prolonging the lifetime of the ice in summer. In addition, they strongly affect how the upper ice surface reflects and absorbs light, and alter living conditions for the myriad organisms associated with sea ice. To help us understand these complex relationships, we need numerical models of snow ice and superimposed ice.

Upward ice growth has been observed in an arctic fjord, Kongsfjorden in Svalbard, where snow and ice thickness and ice freeboard have been measured consistently since 2003. These data provide a test bench where we can explore various processes in the snow and sea ice - processes that play a role in how arctic sea ice changes on a large scale.

Using a high-resolution thermodynamic snow and sea-ice model, we investigated the upward growth of landfast sea ice in Kongsfjorden. The model results show that upward ice growth accounted for about 15% of the total ice mass and 35% of the total ice growth during the simulation period between late January and late May 2004. They also show that weather conditions, in particular air temperature and precipitation, are critical factors for the development of snow ice and superimposed ice in Kongsfjorden. While both warming air and more precipitation led to increased formation of snow ice and superimposed ice in

Kongsfjorden in the model runs, the processes reacted more strongly to precipitation than to air temperature.

At the same time, it is important to note that ice growth processes require existence of sea ice in the first place. In recent years the sea ice season in Kongsfjorden has become shorter, and the extent of the sea ice has shrunk. Still, once sea ice forms, these processes can play a crucial role in the overall ice mass balance.

FURTHER READING

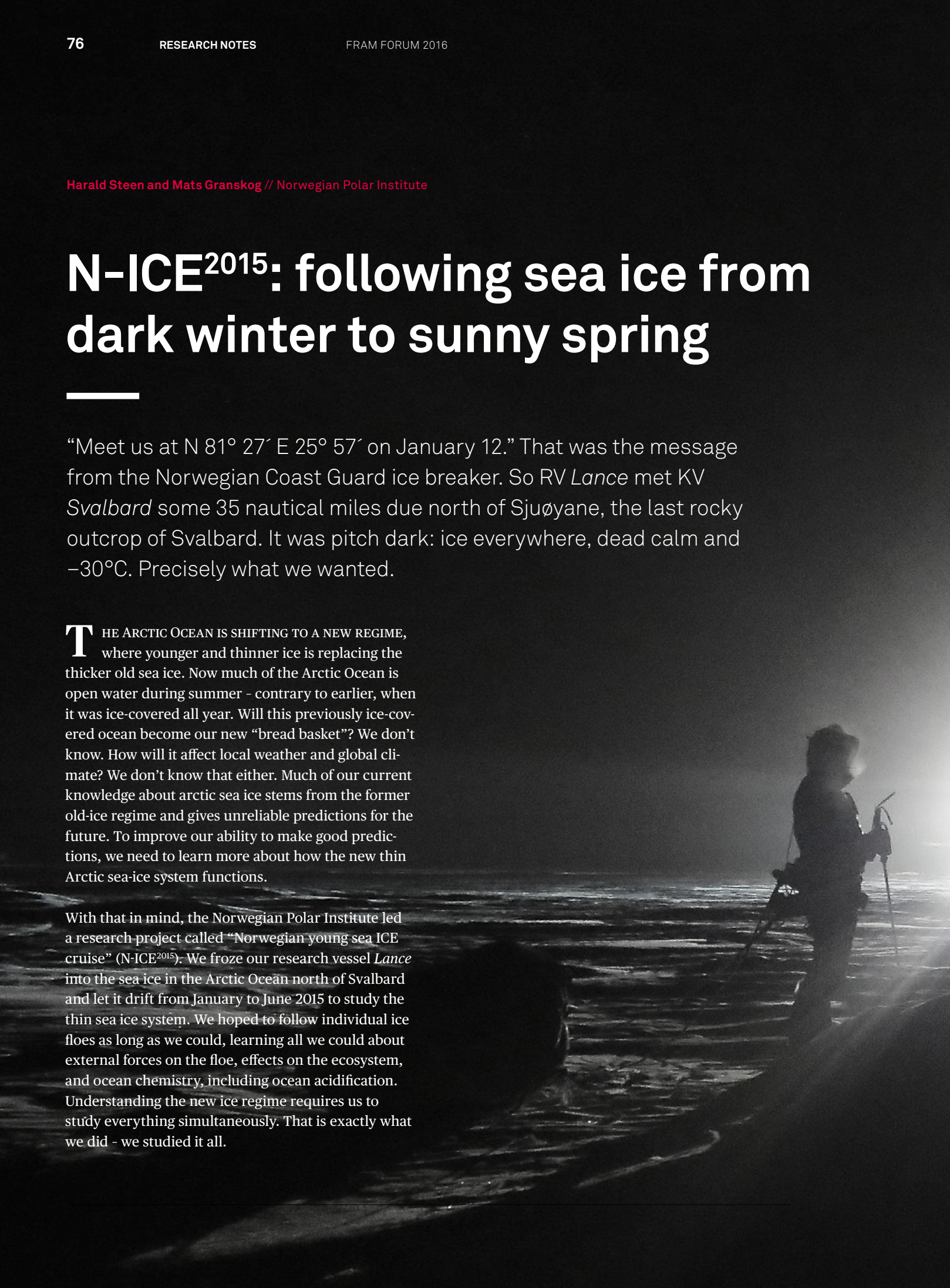
Wang C, Cheng B, Wang K, Gerland S, Pavlova O. (2015) Modelling snow ice and superimposed ice on land-fast sea ice in Kongsfjorden, Svalbard. Polar Research 34, 20828, http://dx.doi.org/10.3402/polar.v34.20828

Fast ice field work in Kongsfjorden, Svalbard.
Photo: Sebastian Gerland, Norwegian Polar Institute

Harald Steen and Mats Granskog // Norwegian Polar Institute

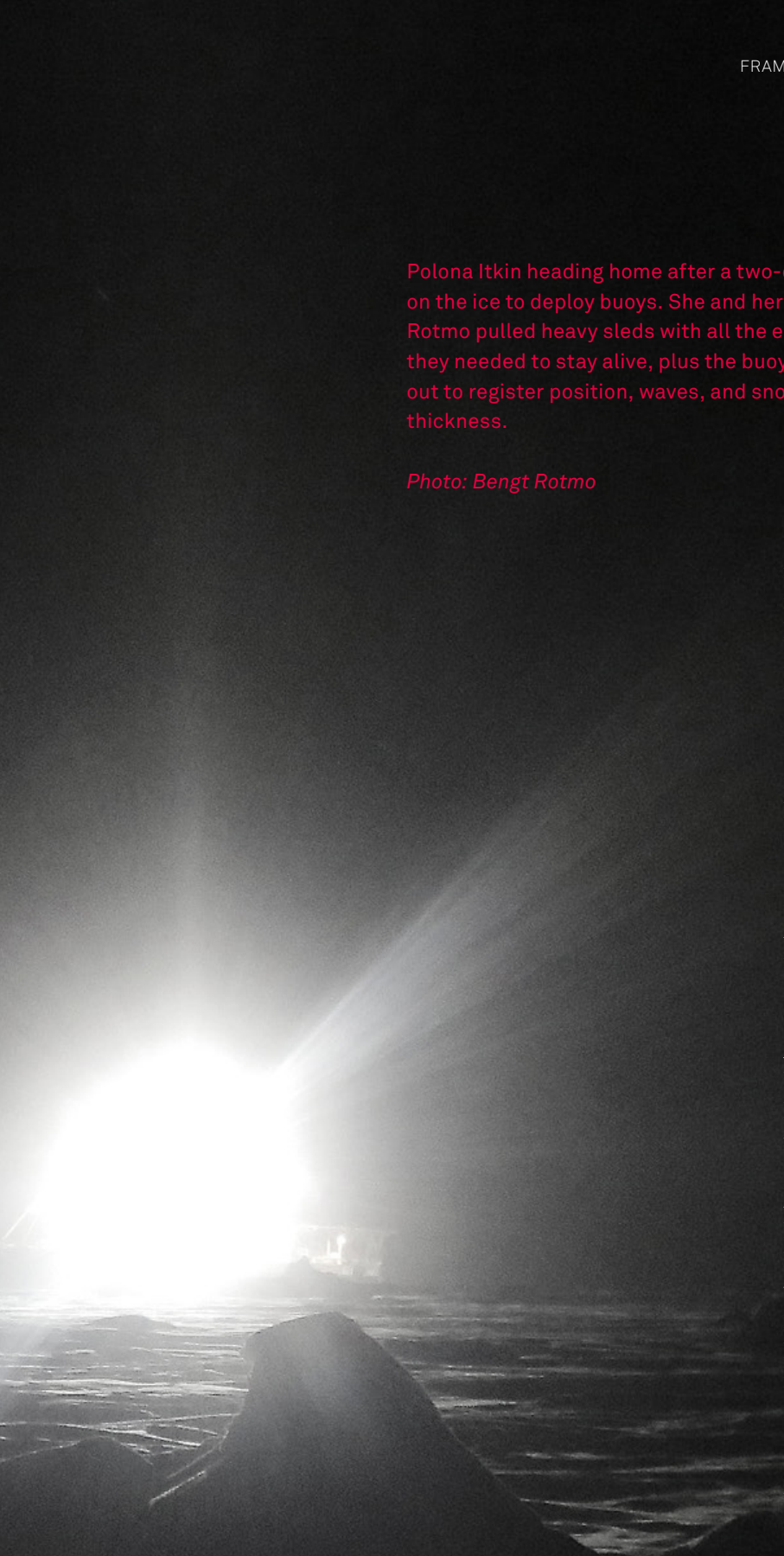
N-ICE^{2015}: following sea ice from dark winter to sunny spring

"Meet us at N 81° 27´ E 25° 57´ on January 12." That was the message from the Norwegian Coast Guard ice breaker. So RV *Lance* met KV *Svalbard* some 35 nautical miles due north of Sjuøyane, the last rocky outcrop of Svalbard. It was pitch dark: ice everywhere, dead calm and –30°C. Precisely what we wanted.



The Arctic Ocean is shifting to a new regime, where younger and thinner ice is replacing the thicker old sea ice. Now much of the Arctic Ocean is open water during summer - contrary to earlier, when it was ice-covered all year. Will this previously ice-covered ocean become our new "bread basket"? We don't know. How will it affect local weather and global climate? We don't know that either. Much of our current knowledge about arctic sea ice stems from the former old-ice regime and gives unreliable predictions for the future. To improve our ability to make good predictions, we need to learn more about how the new thin Arctic sea-ice system functions.

With that in mind, the Norwegian Polar Institute led a research project called "Norwegian young sea ICE cruise" (N-ICE^{2015}). We froze our research vessel *Lance* into the sea ice in the Arctic Ocean north of Svalbard and let it drift from January to June 2015 to study the thin sea ice system. We hoped to follow individual ice floes as long as we could, learning all we could about external forces on the floe, effects on the ecosystem, and ocean chemistry, including ocean acidification. Understanding the new ice regime requires us to study everything simultaneously. That is exactly what we did - we studied it all.



Polona Itkin heading home after a two-day mission on the ice to deploy buoys. She and her guide Bengt Rotmo pulled heavy sleds with all the equipment they needed to stay alive, plus the buoys they set out to register position, waves, and snow and ice thickness.

Photo: Bengt Rotmo

One of our key goals was to understand what causes freezing and melting of the ice in this region. Freezing is reasonably straightforward since it is caused by lack of sun and cold air. Melting also appears obvious: ice melts when exposed to heat (or energy). But the interesting question is where the energy comes from and when. There are two sources of heat - the ocean and the atmosphere. Atlantic water (-+3.0°C) that flows into the Arctic Ocean west of Svalbard is relatively heavy and it sinks down to below the fresher and colder Arctic water. If left alone, it ends up at 70 m depth - where it melts little ice! But it isn't left alone. Storms over open water mix the ocean and bring the warm Atlantic water to the surface. The same storms set the ice adrift, which also causes mixing.

Storms in the Arctic can be fierce. During one storm, *Lance* and the entire ice pack drifted at a speed of 1.2 knots! The temperature rose from -35°C to -2°C in 30 hours, bringing vast amounts of "hot" air into the Arctic. Then it plummeted to -40°C in a couple of hours.

After the dark Polar Night, the sun returns, bringing heat that contributes to ice melt and providing the light that algae need to grow and become food for the whole ecosystem. Understanding the fate of the sunrays is not trivial. Just 10 cm of snow stops most of the light because it is reflected (albedo) or absorbed. That means the amount of energy available to the primary producers in and under the ice depends on snow depth, distribution and ice thickness and quality.

We studied the fate of the Atlantic water by measuring temperature and salinity at different depths throughout the cruise and measured vertical movement of water with a special instrument. Above the ice, turbulent air also moves energy, so we measured air movement with the same type of instrument. The lower atmosphere was studied using a 10-m weather mast mounted on the ice, and conditions up to 30 km

The remote camp in the distance with its 10-m weather mast, instrument hut, and the tent housing water sampling equipment. The helicopter was used to measure ice thickness over larger areas. *Photo: Jennifer King*

altitude with weather balloons launched twice a day. Since the ship interferes with many of these instruments they were installed at what we called the "super site" about 450 m away. The super site was powered by cable from the ship to avoid local contamination by generator exhaust.

The ice thickness is the end result of all the processes described so far, but snow on top of ice complicates matters because it insulates ice and prevents its growth. Throughout the cruise, the sea ice and snow team measured the total thickness of the sea ice and snow with an instrument called EM31, and snow thickness with a glorified yardstick called a magnaprobe. Obviously, people dragging a sled cannot cover large areas, so to broaden our range we measured ice characteristics from a helicopter in spring. Categorising ice from airplanes or satellites is tempting, but we need to calibrate the algorithms these long-range measurements use. To do this, accurate first-hand knowledge of actual conditions is essential. Two projects, ICE-ARC (British Antarctic Survey, Technical University of Denmark, EU, and European Space Agency), and NASA's Operation IceBridge, flew low passes over the ice near the ship, measuring ice thickness, snow and surface characteristics. Just after they had flown over us, we went out and meticulously measured the same area. Satellite images were checked in the same way.

As the ice pack becomes thinner, it appears to be moving faster, and may also be more sensitive to break-up due to storms and waves. We studied waves and ice movement using buoys that transmit data via satellite back to the lab. We deployed buoys twice: once in January and once after Easter. The Easter deployment used helicopter, but the January deployment was special, since the buoys were set out by skiers hauling sleds! Just imagine skiing off into the dark cold artic

Scientists setting up equipment at the remote camp. *Photo: Nick Cobbing*

winter, away from the cozy *Lance* to spend a night or two on an ice floe.

The biologists wanted to find out how organisms living in the sea ice and in the water below adapt to a thinner ice cover. One of the focal questions is whether under-ice phytoplankton blooms may become more widespread in the new ice regime, as seems to be happening elsewhere in the Arctic. Changes in the timing and magnitude of the ice algal and phytoplankton bloom will affect primary consumers and ultimately the entire ice-associated ecosystem. Carbon dioxide lowers the pH in seawater, and ocean acidification may perturb many organisms and threaten the ecosystem. Winter data from this region have been scanty, but during N-ICE^{2015} we measured carbon dioxide in the ocean continuously.

Having a safe, comfortable research station north of Svalbard from winter to summer offered unique research opportunities and N-ICE^{2015} brought together many experts. The project was truly an international expedition with scientists from Canada, Denmark, Finland, France, Germany, Japan, the Republic of Korea, Norway, Russia, the United Kingdom, and the United States. The national and international collaboration strengthened the scientific outcome and increased the output tremendously.

FURTHER READING:

Granskog MA, Assmy P, Gerland S, Spreen G, Steen H, Smedsrud LH. (2016) Arctic research on thin ice: Consequences of Arctic sea ice loss. Eos Trans. AGU, 97. doi:10.1029/2016EO044097

Hans Peter Blankholm // UiT The Arctic University of Norway

Joint proxies – new answers from ancient sites

Imagine an archaeological site with good preservation conditions, containing proxy data of relevance for archaeological, geological, zoological, botanical and climate research and interpretation – all at the same time. A veritable treasure trove of information!

Archaeological sites can be time capsules, where many different types of data converge. A new international and interdisciplinary research group at the Faculty of Humanities, Social Sciences and Education at UiT The Arctic University of Norway now intends to analyse these data - these "joint proxies". By doing so, the research network aims to make an important contribution to regional and global knowledge on how both human and natural populations (fauna and flora) have adapted to global climate change and to one another in the High North through time. Concurrently, they will use the same baseline data to contribute to climate research, particularly by providing information on temperature oscillations on various timescales through the past 10 000 years - from the beginning of the Holocene to the end of the Little Ice Age. This will provide a basis for more precise predictions of how human and natural populations might adapt to various effects of future climate and environmental change.

Sites with good preservation conditions for organic matter are, however, relatively rare in the High North and are also among the most vulnerable to the detrimental effects of global climate change (e.g., riverine and coastal erosion, acidification, thawing of permafrost) and increasing industrialisation of the Arctic and sub-Arctic.

There is an urgent need both to re-investigate already known archaeological sites with joint proxies, and to locate and analyse new such sites with cutting-edge theories, methods and techniques - before it is too late. There is also a need for new sea-cores to obtain information on past sea surface temperatures and isotope profiles from the sea near hot-spots of joint proxy sites.

The general aims of the Joint Proxies Research Group are to investigate *pioneering*, *adaptation strategies*, *management*, and *impact* in relation to *climate change*.

From the excavation of the Finnes site on Ingøy, Vest-Finnmark county, Norway, in 2011. A fine joint proxy site that was inhabited 400 – 200 BC (Early Metal Age) and 1270 – 1400 AD (Medieval times). Bones and organic artefacts are well-preserved in the shell-sand. Associate professor Stephen Wickler from Tromsø University Museum is seen excavating the site.

Test-pitting a joint proxy site from the Younger Stone Age (5000-6000 years before present) situated on a raised, fossil beach at Skjåvika, north-easternmost Finnmark county, Norway, in 2015. Jan Ingolf Kleppe from Finnmark county cultural resource management is at work in this image.

Both photos: H.P. Blankholm, UiT The Arctic University of Norway

A selection of fish-hooks (left) and bones (below) from the Finnes site. Good joint proxy data!

Both photos: Adnan Igacic, Tromsø University Museum

Focal points include:

Spread of humans and biotic resources into the High North, including environmental ranges, dynamics, drivers and mobility

Adaptation and subsistence strategies, including food sources, technology and niche construction

Health and diet, including biogeoaccumulation of heavy metals (e.g., mercury and cadmium) in food webs of the past, present and future

Resource and land management, including incipient herding and agriculture, and

Ecosystem feed-back and resilience, demographies, and intensity and type of impact.

Archaeological sites with good preservation conditions are dependent on alkaline conditions such as those in shell/coral sand and anaerobic alkaline bogs. To improve the chance of finding more sites in bogs, research has also been initiated to detect remote sensing signatures of limestone-dependent wetland plants in high-resolution images.

In early 2015 a new international and interdisciplinary research group was established at the Faculty of Humanities, Social Sciences and Education at UiT The Arctic University of Norway. Their project, entitled "Joint research on human and natural adaptation to changing climates and environments in the High North by proxy data (Joint Proxies)" emanated from a "start-up" grant for 2015-2017 from the Research Council of Norway, under the programme Cultural Conditions Underlying Social Change (SAMKUL). Today the research group consists of 22 scholars from Norway, Sweden, Denmark, England, Scotland, Iceland, Greenland, Canada, and Russia.

From the First Workshop of the Joint Proxies Research Group at the Institute of Archaeology and Social Anthropology 15-17 September 2015. From left to right Peter Rowley-Conwy (University of Durham, England), Ann Eileen Lennert (Greenland Institute of Natural Resources), Kerstin Lidén (University of Stockholm), Patricia Wells (Arctic Institute of North America), Tom Dawson (University of St. Andrews, Scotland), Inger Alsos (UiT The Arctic University of Norway), H.P. Blankholm (UiT and Joint Proxies Research Group leader), Christin Jensen (University of Stavanger), Anders Romundset (Norwegian Geological Survey), Katrine Husum (Norwegian Polar Institute), Bjarne Grønnow (National Museum of Denmark), and Gørill Nilsen (UiT).

Photo: Eva Panagiotakopulu, University of Edinburgh, Scotland

Helge M. Markusson // Fram Centre

The spread of toxic mercury is affecting the Arctic

The transport of environmental contaminants to the Arctic via water and air is a threat to the environment. Research done at the Fram Centre confirms that in the Arctic, methylmercury moves more effectively through the food chain than in more southerly waters.

Methylmercury is a toxic form of mercury that is easily absorbed from the gastrointestinal tract and can cause a number of health problems. Methylmercury represents a significant threat to marine animals at the top of the aquatic food chain. A new study, published in 2015, has confirmed that the tissues of predators in the Arctic have higher concentrations of methylmercury than those of animals lower down the food chain.

"There has been a steeper rise in concentrations of methylmercury through the food chain in the Arctic than has been observed in a number of earlier studies, especially at lower latitudes", says lead author Anders Ruus. The study is part of the Fram Centre's research programme on the impact of environmental contaminants in the High North, in which researchers from eight research institutions have participated.

"The environmental contaminant mercury spreads globally and is transported over long distances from the source of the emissions. There is net deposition of mercury to the Arctic from the atmosphere in the spring. Even though the international community had a global agreement in place in 2013 to reduce mercury levels, this environmental contaminant is still a problem in the Arctic. One of the most important mercury sources is emissions from gold mines and coal combustion", explains Eldbjørg Heimstad, director of research at NILU – the Norwegian Institute for Air Research at the Fram Centre.

"But we also see a corresponding trend for the trace element selenium, which may play a protective role against mercury's toxic effects. As yet we know little about the mechanisms behind this, but they probably involve the formation of metal-binding proteins, or binding of mercury in insoluble selenium compounds", says Anders Ruus.

Selenium is a non-metallic element chemically related to sulphur and tellurium. It is rarer than silver and is poisonous in large amounts (in excess of 5 mg daily), but as a trace element it is essential to life.

The field work involved in the research was carried out in and around the Kongsfjorden system in Svalbard. Samples were taken from zooplankton, fish and birds in three different periods, and the analysis was done at a number of Norwegian laboratories.

"Little auks, which eat zooplankton, have lower levels of methylmercury than kittiwakes, which eat fish and crustaceans. Mercury levels were highest in the spring (May) when methylmercury is also deposited to ice and land. High levels of selenium in the spring in seabirds indicate that selenium is important in mercury detoxification", says Geir Wing Gabrielsen,

Measurements were taken in zooplankton, fish and birds, like the little auk.

Photo: Hallvard Strøm, Norwegian Polar Institute

researcher and head of the environmental pollutants section at the Norwegian Polar Institute.

"The findings confirm the results of earlier research showing that environmental pollutants accumulate and reach greater concentrations in the arctic food web than in systems further south. The findings are an important contribution to our knowledge of heavy metals in the Arctic", says Anders Ruus.

The transport of environmental contaminants to the Arctic via water and air is a threat to nature. The field work was carried out in and around the Kongsfjorden system in Svalbard.

Photo: Helge M. Markusson, Fram Centre

FURTHER READING:

Ruus A, Øverjordet IB, Braaten HFV, Evenset A, Christensen G, Heimstad ES, Gabrielsen GW, Borgå A. (2015) Methylmercury biomagnification in an arctic pelagic food web. Environmental Toxicology and Chemistry 34(11):2636-2643 DOI: 10.1002/etc.3143

Christina A. Pedersen // Norwegian Polar Institute

Twelfth Ny-Ålesund seminar arranged in Tromsø September 2015

In September 2015, eighty-one participants from twelve countries attended the three-day Ny-Ålesund seminar, focused on research and monitoring in Svalbard.

The Ny-Ålesund seminar is a biannual meeting for scientists whose activities take them to Svalbard, and in particular to the tiny research community of Ny-Ålesund. The seminar serves the dual purpose of providing a meeting place to exchange scientific results, advances, and ideas, and fostering coordination and collaboration among researchers in Ny-Ålesund. The 2015 seminar focused on research and monitoring within the four programme areas established for Ny-Ålesund: the Atmosphere Flagship, the Kongsfjorden System Flagship, the Terrestrial Ecology Flagship, and the Glaciology Flagship. In addition, there was a special session on how to connect the research and monitoring done in Ny-Ålesund with activities in the rest of Svalbard and beyond. This session included keynote presentations on ongoing activities in Hornsund, Barentsburg and Longyearbyen. The seminar presentations, 60 in total, spanned from space weather to number size distribution of aerosols, from tundra ecosystem monitoring to microbiota, from migration of the arctic skua to the bathymetry of Kongsfjord, from snow and ice archives to calibration and validation (what the scientists call “cal-val”) for glacier mass balance.

The last day had four parallel sessions, one for each Flagship. The Atmosphere Flagship arranged its own Atmosphere Symposium, with scientific presentations, while the three other flagships had workgroup discussions dealing with future prioritised tasks for the flagships, and flagship organisation. All four flagships have now updated their list of prioritised topics and/or projects, and have developed a structure with a scientific chair, co-chair and a scientific committee. All flagships are open to new participants and ideas at any time. More information is available on the flagships webpages: http://nysmac.npolar.no/research/flagships/

The Atmosphere Flagship submitted a proposal to the “seed money” programme Svalbard Strategic Grant in November requesting support for its activities in the next two years. The main activities are anticipated to take place in smaller work groups focusing on specific scientific questions; six work groups are currently listed, each of which plans to arrange at least one meeting in 2016 or 2017. Anticipated outputs from the work group meetings are joint publications and jointly organised field work.

Seminar participants in Tromsø.
Photo: Ann Kristin Balto, Norwegian Polar Institute

The Terrestrial Ecosystem Flagship outlined four scientific topics that capture its current and future directions. This flagship also intends to organise the work into three operational work-packages. These work-packages overlap thematically to some degree, and may be viewed as three integrated components of the revitalised terrestrial flagship program. The flagship also identified infrastructure and funding needs, and defined its next three action points: a common research proposal, integrative papers, and establishment of common long-term monitoring sites at landscape level.

The Kongsfjorden System Flagship started by reviewing the research priorities from 2008, when the flagship program was established, to assess where there had been good progress and where there had not. The flagship further agreed on five points which summarised the new research priorities. Participants in the flagship agreed that if they are to work together in a concerted effort on research projects, a foundation must first be laid in joint workshops, preferably including participants from the other flagships as well. Four prioritised workshops were agreed on, and a proposal for a workshop on “Adaptation to environmental changes in the Arctic” was submitted to the Svalbard Strategic Grant programme in November.

Birgit Njåstad // Norwegian Polar Institute

Fram Centre and the Arctic Council: celebrating a 20-year-old

The Arctic Council will be 20 years old in 2016. This is a golden opportunity to take stock and reflect on what the Arctic Council means for us at the Fram Centre.

The Arctic Council is an intergovernmental body for political cooperation on issues of common interest to the Arctic States; through coordination, cooperation and interaction, it contributes to moving policy. The Council's basic objective is to promote sustainable development and environmental protection.

The first seeds of the Arctic Council were sown in the "Finnish initiative" from 1991, when the eight Arctic States agreed on and adopted the Arctic Environmental Protection Strategy (AEPS). The work that began in connection with implementing AEPS formed the core of what would later become the Arctic Council.

With the formal establishment of the Arctic Council in 1996, the ongoing cooperation within AEPS was broadened to include sustainable development. The eight Arctic States and six organisations representing Arctic indigenous peoples are permanent members of the Arctic Council. Several non-Arctic states, international governmental and non-governmental organisations have observer status in the Council, and a growing number of organisations are showing interest in attaining observer status.

Right from the start, a key aspect of the Council's activity has been to collate knowledge about the environment and environmental change as a basis for assessing the need for measures and developing policy. Through its working groups *Arctic Monitoring and Assessment Programme* (AMAP), *Conservation of Arctic Flora and Fauna* (CAFF), *Protection of the Arctic Marine Environment* (PAME) and *Environmental Prevention, Preparedness and Response* (EPPR), the Council has prompted the scientific communities to produce high-quality, peer-reviewed "pioneering" reports based on the most recent research and monitoring. These have contributed not only to policy development in the Council's Member States, but also to global environmental and climate processes.

AMAP's reports on persistent organic pollutants and climate change in the Arctic (see text box) are good examples of work that has been important in the international arena, including the Stockholm Convention and the United Nations' work on climate change. Similarly, CAFF's work has provided input to the Convention on Biological Diversity and the International Union for Conservation of Nature, and PAME's work has had significance for discussions in the International Maritime Organisation.

Individual member institutions of the Fram Centre, such as the Norwegian Polar Institute, the Institute of Marine Research, Akvaplan-niva and UiT The Arctic University of Norway, have always been actively engaged in the processes leading to the Arctic Council's scientific assessment reports, and Fram Centre staff serve as administrative coordinators, expert contributors and peer reviewers. Publishing these reports is often a complicated process, driven not only by their inherent scientific value, but also in part by a need to maintain Norwegian engagement.

The assessment reports are based on published scientific findings. Through their research, the institutions in the Fram Centre have contributed to the knowledge base presented to the Arctic States to serve as a common platform for developing measures and policy in the Arctic.

The Arctic Council does not conduct research itself; nor does it fund research. However, it does identify knowledge gaps that impede Member States' efforts to select and implement management measures and to develop policy. This information may in turn influence national prioritisations related to research funding.

Topics that will be high on the Arctic Council's agenda in coming years include opportunities, limitations and challenges linked to increased human activity in the Arctic Ocean, consequences of and adaptation to climate change, and the need to improve economic and other living conditions for the inhabitants of the Arctic.

The Arctic Council flag flying over a Senior Arctic Officials meeting in Haparanda, Sweden.
Photo: Linnea Nordström, Arctic Council Secretariat

Let us pause at this point to reflect on the Fram Centre's opportunities for interaction with the 20-year-old Arctic Council. The mission of FRAM – High North Research Centre for Climate and the Environment – is to help maintain Norway's position as a leader in northern environmental and natural resource management, and to strengthen knowledge about climate and the environment as the basis for sound, responsible management, climate change adaptation and societal planning in the High North. This mission is in perfect harmony with the Arctic Council's vision that its Member States work together to promote environmentally, socially and economically sustainable development.

If we consider the Arctic Council's specific areas of focus for the next few years – the Arctic Ocean, climate change and living conditions – it is evident that these key areas coincide closely with those of the Fram Centre's flagship research programmes.

The Arctic Council has now established its permanent secretariat at the Fram Centre in Tromsø, making information about the Council, its current activities and knowledge requirements readily accessible to Fram Centre member institutions.

The conditions are thus ideal for Fram Centre partners to target their research priorities towards closing knowledge gaps and advancing the knowledge forefront in areas the Arctic Council has identified as especially important. To take advantage of this potential and further increase the visibility of the Fram Centre and its work in these areas, Fram Centre institutions and personnel should spring to action, inspired by the knowledge needs the Arctic States, through the Arctic Council, have identified as a prerequisite for sound governance of the Arctic.

Further reading: www.arctic-council.org

A SELECTION OF AMAP ASSESSMENT REPORTS

- Arctic Pollution Issues, 1997
- Persistent Organic Pollutants in the Arctic, 2002
- Arctic Pollution, 2006
- Persistent Organic Pollutants, Radioactivity, Human Health, 2009
- Arctic Climate Impact Assessment, 2005
- Snow, Water, Ice and Permafrost in the Arctic SWIPA, 2011
- Climate Change and the Cryosphere, 2011

Helge M. Markusson // Fram Centre

Complex impact of mining activity around Norwegian fjords

Mining leaves its mark on nature and the landscape and the topic is almost without exception controversial. In recent years, the conflict has mainly been about the future dumping of waste rock and debris from mining into Førdefjord in the county of Sogn og Fjordane and into Repparfjord in the county of Finnmark. To put it very simply: on one side we have the mining companies in alliance with those who see the opportunities for creating new jobs, while on the other we have the fishing industry in alliance with the environmentalists.

Two quotes illustrate the conflict:
"The Ministry of Trade, Industry and Fisheries believes that the zoning plan is good enough to enable the establishment of mining with deep-water disposal of tailings in the Repparfjord. A decision on the zoning plan will be made by the Ministry of Local Government and Modernisation." *Regjeringen.no*

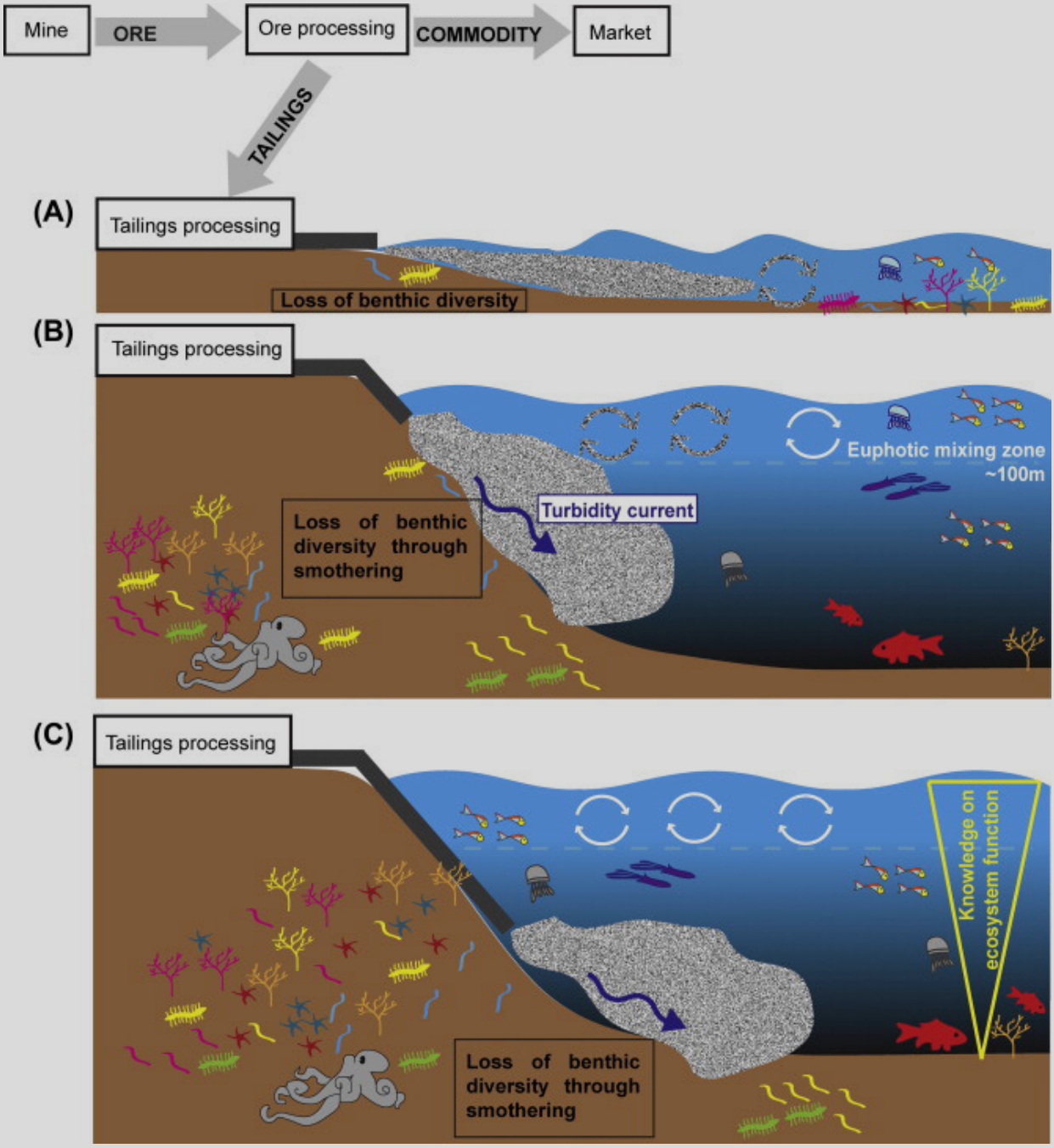
"The mining company Nussir ASA has applied for a licence to dump 17 truckloads of waste rock containing copper every hour, every day for the next 20 years into the Repparfjord in West Finnmark. Previous history from the Folldal mines in the 1970s shows that the fish community was badly impacted by the dumping of copper-containing debris. The content of heavy metals in the waste rock is so high that it will be acutely toxic for many marine organisms. The Sami Parliament and the District Board for West Finnmark have objected to the plans, and the matter has been sent to the Ministry of Climate and Environment for decision." *Natur og Ungdom, nu.no*

A cross-disciplinary team of researchers reviewed the dumping of mine tailings, mainly from a Norwegian perspective. The work was done as part of the Fram Centre's collaborative research project "MIKON – The environmental impacts of industrial activity in the North" and a report was recently published in the Marine Pollution Bulletin. Lead author, marine biologist Eva Ramirez-Llodra at the Norwegian Institute for Water Research (NIVA), summarises the issue thus: "The scientific and social problems which arise from dumping waste rock from mining into the fjord are complex and rarely considered as a totality."

Lead author Eva Ramirez-Llodra.
Photo: Norwegian Institute for Water Research

FURTHER READING:

Ramirez-Llodra E, Trannum HC, Evenset A, Levin LA, Andersson M, Finne TE, Hilario A, Flem B, Christensen G, Schaanning M, Vanreusel A. (2015) Submarine and deep-sea mine tailing placements: A review of current practices, environmental issues, natural analogs and knowledge gaps in Norway and internationally. Marine Pollution Bulletin 97(1-2):13-35



In the process of extracting metal from ore, the parent rock is crushed into fine particles. The desired metal can often be as little as a few percent of the total rock weight. The waste that remains after extraction – called tailings – must be disposed of. Although the metal of interest has been removed, tailings contain many other potentially toxic substances. Most tailings are dumped on land, sometimes in abandoned mines, but more often in dams. The collapse of one such dam resulted in the deadly toxic mudslide in Minas Gerais, Brazil last November. Despite environmental regulations, mine tailings are disposed of in rivers in some countries. This also leads to extensive environmental damage. Increasingly, tailings are now being deposited in the ocean. However, marine disposal is not without environmental impact, as shown in this figure.

Coastal disposal (panel A) involves dumping the tailings near the surface in shallow areas. Some material will be mixed into the sunlit water layer where photosynthesis can occur. In *submarine disposal* (panel B) the tailings are ejected through a pipeline at less than 100 m depth. As before, some material will end up in the photic water zone. In *deep-sea tailings placement* (panel C), the material is released well below the photic zone. All three methods deposit tailings on the seabed, where they will have impact on species diversity. The overall effects are difficult to predict. Least is known about ecosystems at great depth. In Norway, the current trend is to shift from submarine disposal to deep-sea placement.

Reprinted from Ramirez-Llodra et al, Marine Pollution Bulletin 2015, 97:13-35 with permission from Elsevier.

Malin Avenius // Science journalist

Ecosystems under pressure put pressure on scientists

From individuals to species to the entire food web – climate change is noticeable at all levels of the arctic marine ecosystem. But no one knows how much the system can tolerate. What we know for certain is that everything is interconnected and significantly more research is needed.

In September 2014, tens of thousands of walruses were observed on a beach near Point Lay in Alaska, and aerial photographs showing the animals jam-packed together were published in newspapers all over the world. Research scientists believe it is the lack of sea ice that has made females and young haul out to rest on land a couple weeks' swim away from the mussel banks where they find their most important food supply.

"The changes we are observing in the arctic ecosystem have to do with a number of stressors that have major impact on biological and biogeochemical processes, the interaction between animal predators and their prey, and the entire dynamics of the ecosystem", said Jacqueline Grebmeier, research professor at the University of Maryland's Center for Environmental Science and keynote speaker at the first FRAM Science Days.

"It's about there being less sea ice, warmer water, changes in food supply, marine pollution and migration northwards", she continued.

NEW BOTTOM-LIVING SPECIES

In the western Arctic, grey whales are migrating ever further north in the hunt for food, and the endangered spectacled eider duck, a specialised diver that uses sea ice as a platform, is having ever greater difficulties finding food. The results Jacqueline Grebmeier presented included new bottom-living species establishing themselves around the Bering Strait; this is changing the conditions that sustain birds and marine mammals. But the connection between these things is both complicated and largely unknown, and researchers need considerably more data that cover both long periods of time and large geographical areas in the Arctic. She also pointed out that we need better knowledge of seasonal variations and we need to work in a more interdisciplinary manner – summarising in advance several of the recurring themes of the two-day conference.

GATHERED AT THE ICE'S EDGE

If the spectacled eider in the western Arctic uses sea ice when it searches for food, the black-legged kittiwake benefits from the ice in Svalbard's glaciers. Together with the ivory gull, fulmar, glaucous gull and black guillemot, the black-legged kittiwake is enticed by the rich food supply to be found where glaciers meet the sea, said Hallvard Strøm from the Norwegian Polar Institute.

"The phenomenon of a large number of seabirds gathering at a glacier's edge is well-known, but not well-documented. We don't know quite what they eat there, but the stomachs of seabirds caught close to glaciers contain krill, naked sea butterfly and arctic cod."

Ringed seals and beluga whales also gather at the seaward edge of the glaciers around Svalbard, which make up a total of 860 kilometres. As yet. The researchers don't know what the ongoing melting of these glaciers will mean for birds and mammals in the future.

The first FRAM Science Days attracted more than 100 delegates.
Photo: Helge M. Markusson, Fram Centre

ICE MELTING AWAY IN GREENLAND

In Greenland, Helen Johnson, from the Universities of Oxford, UK, and Bergen, Norway, is also studying the area where glaciers meet the sea, but from a completely different perspective. She is a physical oceanographer and is studying what happens hydrographically in fjords where glaciers flow into the sea. In recent decades, the melting of Greenland's inland ice has quadrupled, and contributed one fourth of the global rise in sea level. But the melting affects the marine environment in several other ways as well.
"The freshwater from melting glaciers is becoming a significant factor in the polar oceans, and may affect the deep water circulation and the climate. Locally, it creates stress in the ecosystem by altering the stratification between water masses and by bringing more nutrients into the sea. This can change the primary production and the structure of the food web", she explained.

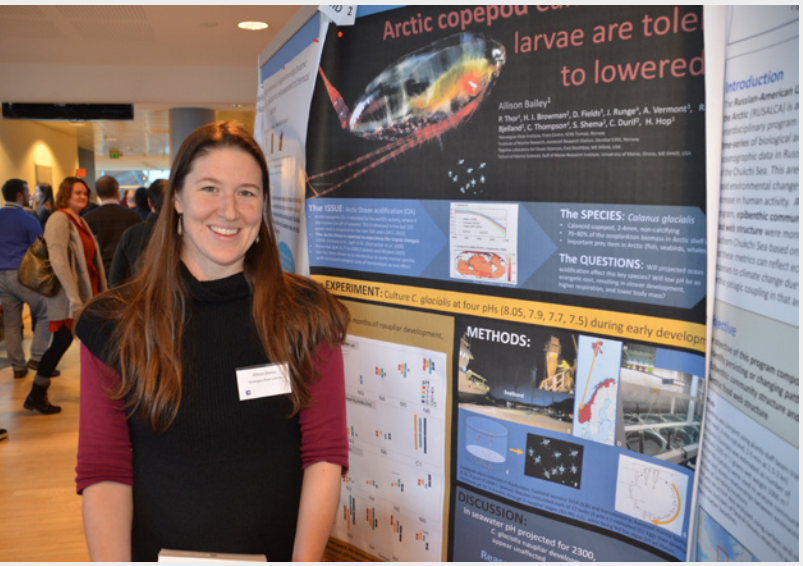
THINNER ICE

Another change in the arctic environment that was discussed at the FRAM Science Days 2015 was the increase in the amount of solar radiation that reaches the seawater. This has to do with less and thinner ice and – above all – with there being less snow to reflect the light waves. Eight times more radiation is now penetrating to the marine ecosystem, said Mats Granskog of the Norwegian Polar Institute. How this will affect microalgae, the very basis of the food web, remains to be seen, and is intertwined with the effects of other stressors.

"The consequences of increased solar radiation cannot be studied in isolation. Factors like warming, larger amounts of freshwater, ocean acidification and more light together affect the biogeochemical processes, often in unpredictable ways."

A NIGHTMARE

"Multiple stressors are a nightmare." This was how Howard Browman of the Institute of Marine Research described the same problem, and he believes that everyone who works with laboratory experiments is well aware of it. His presentation described recent efforts to learn more about ocean acidification, which is caused by the ocean absorbing much of the carbon dioxide we emit into the atmosphere. He exhorted his colleagues to adopt an organised scepticism to the multitude of reports showing how a lower pH value affects different organisms, since many authors have forgotten to factor in natural selection over the course of several generations – forgotten how much animals can adapt and how much the acidity can vary in their natural habitats.
"Instead of focusing solely on the individuals that died in an experiment, we should look at those who survived. If one group actually coped well, that can be important in the longer term."



Poster award for PhD and Master's students – FRAM Science Days 2015. Winner: Allison Bailey and co-workers. Theme: Multi-stressors in the Arctic Marine Ecosystem. Poster title: Arctic copepod *Calanus glacialis* larvae are tolerant to lowered pH.

A good poster should have a clear, simple message, yet provide sufficient information for the reader to understand the study's hypothesis, methods, and results. Good illustrations are also a plus! Bailey is doing her PhD at the Norwegian Polar Institute.

Photo: Helge M. Markusson, Fram Centre

CHANGES IN THE ECOSYSTEM

Rather than studying the sensitivity of individuals and individual species, Raul Primicerio at UiT The Arctic University of Norway has devoted himself to studying the entire ecosystem. As keynote speaker on the second day of the conference, he introduced the session entitled Ecosystem Changes. His primary focus is not the direct effects of environmental change on animal life (such as the fact that cod and haddock have migrated further north), but the impact of such changes on the sensitivity of the entire ecosystem – which will determine, for example, how much pressure from fisheries the Barents Sea will be able to cope with in the future.

"When it comes to individuals, we have the tools to study how sensitive they are, but as yet we don't have those tools for the entire ecosystem. If we want to achieve ecosystem-based management, that's something we have to work on", he told the audience.

WE NEED ECOSYSTEM PROGNOSES

Lis Jørgensen, of the Institute of Marine Research, also called for the tools to enable wise future management of the ecosystem, and said we must become better at identifying human activity that impacts negatively on the system.

"We need to be able to make ecosystem prognoses, roughly the same way as we predict the weather!"

Along the Norwegian coast from Trondheim and northward, an ongoing change no one had predicted shows that not all transformation of the ecosystem is necessarily a bad thing. In places where sea urchins had taken over and transformed billowing kelp forests into desert-like ocean floors, the long brown algae are now returning. And with them, an ecosystem is being re-established – an ecosystem that is very important for biological diversity along the coast, said Hartwig Christie of the Norwegian Institute for Water Research (NIVA).

"We don't know why the sea urchin population was so successful 45 years ago, but we are now carefully monitoring its decline. It is a cold-water species and is under stress, mainly because the water is becoming warmer, but it is also being eaten by invasive snow crabs and king crabs. Their role is something we need to study in greater detail."

REMOTE ANALYSIS PROVIDES KNOWLEDGE

Even if many of the speakers at the FRAM Science Days observed that we still lack a great deal of knowledge about the marine ecosystem in the Arctic, Rolf Gradinger of the University of Alaska Fairbanks and the Institute of Marine Research pointed out that there is also a great deal we *do* know.

"Thanks to remote analysis, we have detailed and comprehensive knowledge of the sea ice, its distribution, concentration, seasonal variations and drift."

Gradinger also hopes that DNA technology will come to good use in future mapping of organisms in the sea.

At the concluding panel debate there was widespread agreement that interdisciplinary cooperation is vital for progress, likewise that the Arctic ecosystem offers a major future challenge for researchers. The end of Rolf Gradinger's presentation captured perfectly the conference delegates' enthusiasm for the task: "It will be great fun and very exciting to be a part of it all."

At the award ceremony. Left to right: Jo Jorem Aarseth, Fram Centre research coordinator and Fram Award jury member, Are Johnsen, general manager of the Fram Centre, who presented the awards, and the award winners, professors Jørgen Berge, Nigel Gilles Yoccoz and Rolf Anker Ims.
Photo: Helge M. Markusson, Fram Centre

Randi Merete Solhaug // UiT The Arctic University of Norway

Fram Awards to professors at UiT The Arctic University of Norway

UiT swept the board at the presentation of the Fram Centre's awards for 2015. Rolf A. Ims and Nigel Yoccoz received the Fram Centre's Research Award and Jørgen Berge received the Research Dissemination Award at Fram Day 2015. All three belong to the Department of Arctic and Marine Biology.

The jury commended Rolf Ims and Nigel Yoccoz for contributing significant new knowledge – often knowledge that has shifted the research focus within their field. One of their ongoing projects is presented on page 36. The award winners are also very active at the Fram Centre, thus promoting interdisciplinary cooperation.

According to the jury, there was no doubt that Jørgen Berge was a worthy winner of the Research Dissemination Award. For several years, Berge has been a prominent, dedicated and skilled disseminator of the work done in his area of research. He also frequently presents his research to the public on his own initiative.

All researchers and research disseminators who work at the Fram Centre and in the Fram Centre's member institutions, as well as other national and international cooperation partners, are eligible to be nominated for the Fram Centre's two awards. The candidates' fields must be related to work undertaken in the Fram Centre's six flagship scientific research programmes.

Over 150 people attended the fifth Fram Day, which is an annual event aimed at fostering interdisciplinary cooperation, greater professional and social contact, and better and broader dissemination of research. The target group for the event is the Fram Centre's members, cooperation partners and the media.

Helge M. Markusson // Fram Centre
Trude Borch // Akvaplan-niva

Arctic Frontiers beats all records

In its tenth year, Arctic Frontiers has beaten all records – for the number of participants, side-events and target groups.

With around 2 000 participants over the six days the event lasts, Arctic Frontiers is the most well-attended annual conference on pan-Arctic issues. The conference theme "Industry and Environment" was clearly an appropriate choice, reflected in the number of delegates. After the opening ceremony at the Fram Centre on Sunday, 24 January, the next five days were set for a large international gathering of politicians, business leaders, influential voices from various organisations, and the press. New this year was a strengthened focus on Arctic Frontiers YOUNG and a number of free events open to the people of Tromsø under the Open Arctic umbrella.

POLITICS

It is 20 years since the Arctic Council was established, and Arctic Frontiers was the arena in which Norwegian authorities celebrated the anniversary. The fact that Tromsø hosts the Arctic Council's Secretariat has undoubtedly had a positive effect for both the city's status as Arctic capital and the Arctic Frontiers conference itself. Ahead of the conference some historians had questioned whether the Arctic Council has achieved much apart from research cooperation on the status of the environment. The Norwegian Minister of Foreign Affairs Børge Brende countered this, however, saying that the cooperation that takes place within the Arctic Council is absolutely unique, an ideal model for supranational regional cooperation also in other parts of the world.

The EU has long had observer status in the Arctic Council. Miroslav Lajkac, the Minister of Foreign Affairs of Slovakia – the country slated to hold the next presidency of the EU – emphasised the great importance the EU attaches to Arctic issues. "Developments in the Arctic, not least on the environmental front, are just as important for us in the EU as they are for the Arctic States", said Lajkac. "Nowhere else can we see the effects of climate change as clearly as here."

It was interesting to listen to David Balton, one of the people in charge of the United States' work within the Arctic Council (and also US Assistant Deputy State Secretary for Oceans and Fisheries). Balton talked about "A New Arctic Ocean" and referred to the UN's first World Ocean Assessment, which concluded that the world's oceans are in trouble. "[The Arctic Ocean is] unlike other oceans. This is not an area with major political conflicts. Most of the national borders we agree on – at least the USA and Russia are in agreement about their border. But we don't know enough yet about what will happen when the fisheries move

Norwegian Prime Minister Erna Solberg opening the session on Industry and Environment at Arctic Frontiers 2016.

Photo: Pernille Ingebrigtsen, Arctic Frontiers

ever further northwards. To know more, we need more research. We have to wait until we can achieve sustainable management of this region before we can open it up", said Balton.

He also mentioned ocean acidification as an issue we need to be aware of. "We know too little and we need more research", was Balton's conclusion. He also launched the idea of establishing an "Arctic Regional Seas Program".

Irrespective of the overarching theme of this year's Arctic Frontiers, climate is always a key topic of discussion. Kristina Persson, the Swedish Minister for Strategic Development and Nordic Cooperation, said that it is a matter of urgency for the Arctic States and the EU to resolve the environmental problems in the High North. "We risk the effects of climate change in the Arctic becoming irreversible. We therefore have a special responsibility to work to prevent that happening", she said.

Norway's Foreign Affairs Minister, Børge Brende, followed this up in his opening speech at the Arctic Frontiers Policy session, saying: "The climate change we are seeing globally is most evident in the Arctic. We therefore need knowledge of how climate change is affecting us." He pointed out that Norway, with its long history as an Arctic coastal nation, has a particular responsibility to work towards sustainable development in the High North. In his speech at Arctic Frontiers Plus, Brende also focused on the oceans, on the importance of maritime law for Arctic cooperation, and on green innovation and "Blue Growth".

INDUSTRIAL DEVELOPMENT

Ocean resources and maritime industries were the theme of the business-related part of Arctic Frontiers. This year's Arctic Frontiers Business sessions were opened by the Norwegian Prime Minister, Erna Solberg, who emphasised the importance of Norway succeeding in the transition from a petroleum-dependent economy to a future industrial economy in which Norway applies its marine expertise to invest more broadly in a number of ocean and maritime industries (seafood, petroleum, renewable energy, mineral extraction). The speakers who followed focused on technological development and technology transfer between the various industries. Several pointed out that even if technology transfer is hailed today as something new, advances in technology and knowledge have always been adopted and put to use in completely different contexts. "I cannot think of a single technological field where we haven't borrowed all through history", said Trond Williksen, director of the AKVA Group.

He reminded the conference delegates that it was the experience we gleaned using concrete to build hydropower plants that formed the knowledge base that allowed us to build our enormous oil platforms at sea. We took the idea for aquaculture pens and cages from the fisheries industry, and today the wild fisheries industry has "borrowed back" the technology from the fish farming industry to develop systems for storage of live cod. Innovation Norway dealt with this topic during a side event at the Business sessions.

One of the most interesting talks during the Business sessions was held by Michael Perkinson, Chief of Staff to the Chief Investment Officer at Guggenheim Partners – a fund that manages 200 billion US dollars. He, too, expressed faith in future investment in renewable marine resources in the High North. "I can't imagine it's likely that we'll see investment in a deep-water industrial harbour soon, but I do believe that investment in the seafood industry will increase. That a number of fish species are migrating further and further north is not necessarily simply a challenge. It can also mean renewable and sustainable industry in the Arctic Ocean", said Perkinson.

DEVELOPMENT

In Arctic Frontiers Science, the part of the conference devoted to scientific research, the focus was also on the ocean, with presentations of research results on such themes as environmental toxins and seabirds, marine waste and debris, oil pollution preparedness, and risk management. The conference was divided into three parallel sessions: Environmental Footprints, Arctic Stewardship, and Technology Needs. At the latter, delegates heard presentations focusing on the technology needs of future arctic and maritime industries.

One of the themes discussed here was taken from the Business sessions and concerned the transfer of technology from offshore petroleum to offshore aquaculture. Hans Bjelland from SINTEF talked about the work done by EXPOSED, a Centre for Research-based Innovation. Bjelland started by saying "We have seen a gradual development whereby fish farming facilities are being established in more exposed locations." He went on to explain that the reason for this was the need for more space, for better circulation so as to avoid pollution, and for greater distances between farming facilities to prevent the spread of disease, as well as the need to maintain a distance from wild salmon populations. The EXPOSED project, which is headed by Bjelland, is developing technology which will allow farming facilities to be taken even further out to sea. The technological focus is on four areas: automation, monitoring technologies, structures/materials technology, and the design of service vessels for the farming industry.

This year, Arctic Frontiers Science received 170 abstracts. A competition was held among the 80 projects that were presented as posters. After careful consideration, the jury gave the annual "Nansen Poster Award for Early Career Scientists" to Daria Gritsenko of the University of Helsinki, for her excellent presentation "Ukraine and the Arctic. Apples and Oranges".

To sum up, Arctic Frontiers 2016 featured a sea of people, many of whom were focused on the sea, on ocean resources, and on vulnerable marine ecosystems in the Arctic.

Helge M. Markusson // Fram Centre

Cornerstone laid for Fram Centre II

The cornerstone for the Fram Centre's building phase II was laid on 25 January 2016. The Fram Centre is a collection of institutions that work with climate and environmental research. The new building will give the Fram Centre nearly twice as much space as before.

Climate and Environment Minister Vidar Helgesen laid the cornerstone for the second building phase of the Fram Centre in January this year.

Photo: Ann Kristin Balto, Norwegian Polar Institute

"Norway is in transition", says Vidar Helgesen, the Minister of Climate and Environment. "We are working to achieve green competitiveness in a sustainable society, and research is absolutely essential. The Fram Centre is an important part of the government's investment in knowledge and the High North. The new building will give us an even better arena for interdisciplinary research and innovation."

The largest new tenant in the expanded building will be the Institute of Marine Research. BarentsWatch will also be able to move back into the building when there is more space.

"In Norway, two things are particularly important for our economic prosperity: our natural resources and the knowledge and expertise required to create value from those resources. When the Institute of Marine Research takes its place in the Fram Centre we will be strengthening Norway's role as a knowledge provider in the realm of marine resources", explains Fisheries Minister Per Sandberg.

Sissel Rogne, Director of the Institute of Marine Research, says that the co-location of a large number of scientific research institutions brings with it many benefits, one of which is more effective collaboration between the various institutions that are gathering knowledge about the High North.

"In addition, a well-designed building can create arenas for both scientific development and social solidarity. These are also important gains that co-location of this nature can provide", she says.

When the second building phase is completed, there will be about 500 jobs in the Fram Centre. An important part of the development is new laboratories and more shared meeting points.

"This will be a modern building. We're using environmentally friendly materials, which will ensure a good indoor environment and extremely low energy requirements. In other words, this will be built to 'passive house' energy performance standards", says Climate and Environment Minister Vidar Helgesen.

"I view the Fram Centre as a very concrete investment in the North on the part of the politicians, and Fram Centre II will reinforce that investment further. Today is a day for celebration. And besides, this part of the city centre will become even more beautiful", says the leader of the Fram Centre, Anne Husebekk.

Construction is planned to start in March, and if all goes according to plan, the building will be ready for occupation during the course of 2018. The builder is the Norwegian Directorate of Public Construction and Property, Statsbygg.

Ivar Stokkeland // Chief Librarian, Norwegian Polar Institute

New books in 2015

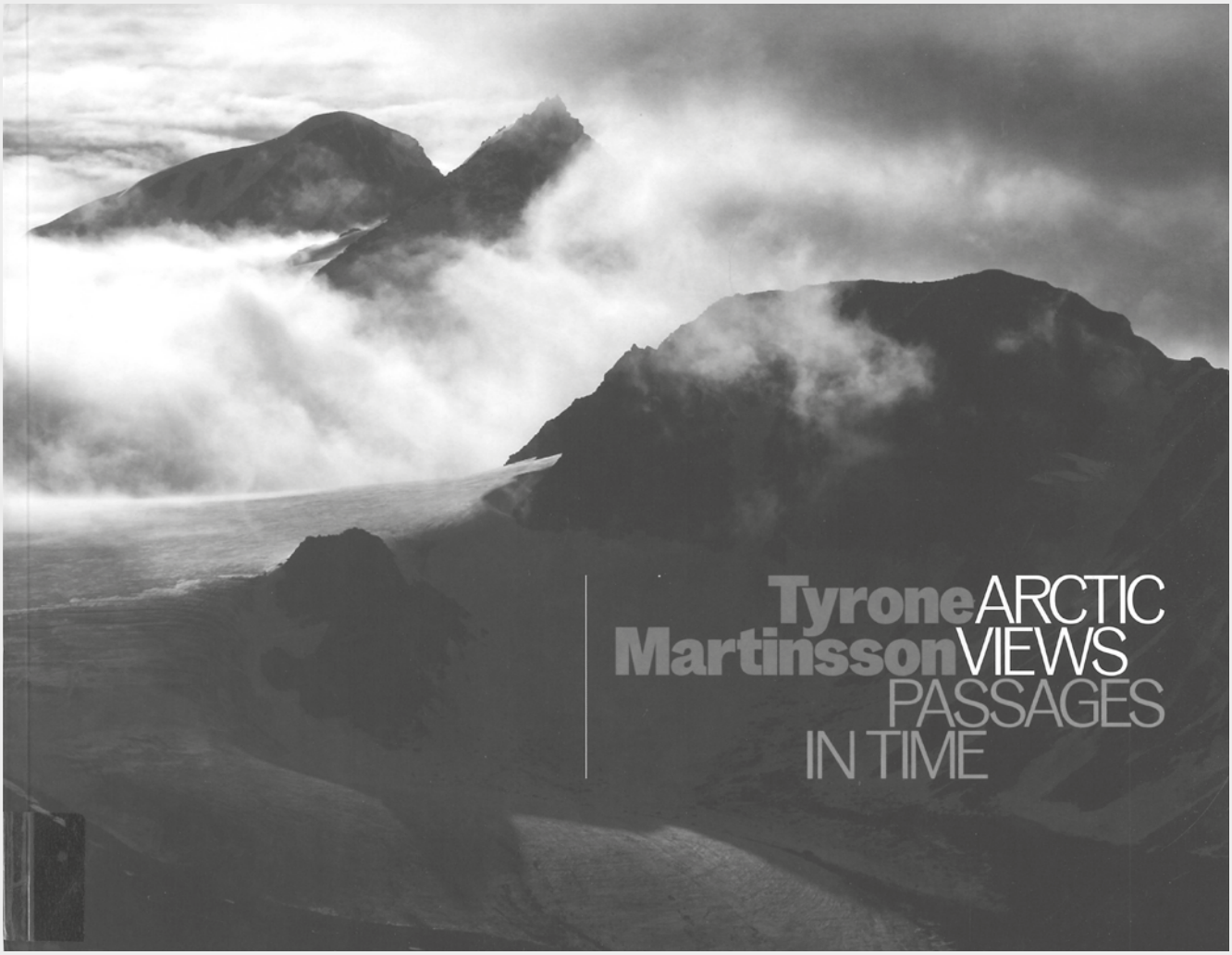
Some interesting additions to the Norwegian Polar Institute library

The Changing Arctic Environment: The Arctic Messenger
David P. Stone. Cambridge University Press. 360 pp.
David P. Stone is a veteran of arctic research. Among other things, he was director of the Arctic Monitoring and Assessment Programme (AMAP) back in the 1990s, and was involved in helping start up the University of the Arctic. The author makes it clear that his book is not an objective summary but a personal report on the available evidence of the changing environment in the Arctic, and what this means for the planet. Key words are persistent organic pollutants (POPs), mercury and climate change. David P. Stone is particularly good at explaining complex processes for non-experts.

Sea Ice: Physics and Remote Sensing
Mohammed Shokr and Nirmal Sinha. AGU/Wiley. 600 pp. (Geophysical monograph; 209)
Based on Canadian research, the authors provide a thorough review of the physics and structure of sea ice, of the laboratory technology and measuring techniques used to map the various properties of the ice, and more. The book is richly illustrated, and particularly worth mentioning are the excellent detail illustrations of the crystalline structure of the various categories of ice.

Arctic Views: Passages in Time
Tyrone Martinsson. Stockholm: Art and Theory. 135 pp.
Dr. Martinsson has for many years studied the history and archaeology of photographic images. He is interested in how our view of nature and landscape changes over time, often in an Arctic setting. In this beautiful book, he invites us both to indulge in recent images from northwestern Svalbard and to compare them with images from historic sources. He also includes highly interesting passages from old diaries and journals. We can definitely recommend spending a few hours in joyful study of this delightful piece of work.

The Ice is Melting – Ethics in the Arctic
Edited by Leif Magne Helgesen, Kim Holmén and Ole Arve Misund. Fagbokforlaget, 245 pp.
This anthology results from an unusual collaboration between science and the church. The book's stated objective is to inform readers about climate change but, more importantly, it challenges them to reflect on the ethical aspects of a warming climate. Chapters discussing the roots and possible consequences of climate change are interspersed with fact-filled chapters on resources and the potential for commercial activity in a warming Arctic. Several of the authors work at Fram Centre institutions.



The State of Marine Microplastic Pollution in the Arctic
by Alice M. Trevail, Susanne Kühn and Geir W. Gabrielsen. 24 pp. (Norwegian Polar Institute. Brief report; 33)
This report is a review of the literature on the state of marine microplastic pollution in the Arctic, which highlights the fact that there are great gaps in our knowledge of the topic. Microplastics are defined as plastic materials that are less than 5 mm in diameter. This very serious source of marine pollution is known from investigations further south, but has been little studied in the Arctic. The report shows that there are already significant amounts of microplastics in sea ice, which will be released straight into the ocean when the ice melts. The microplastics represent a major stress factor for various animal species (plankton, fish, seabirds) and are thus a threat to Arctic marine ecosystems. The report is available in print, and can also be accessed free of charge from the Norwegian Polar Institute's digital publications archive "Brage NP".

Fangsthytter på Svalbard 1794–2015 [Trappers' huts in Svalbard 1794–2015]
Per Kyrre Reymert and Oddleif Moen. (Svalbard Museums skrifter; 2). 711 pp.
Finally, we must mention a new Norwegian title. Even non-Norwegian speakers will find this book rewarding and enjoyable. Many years of collecting and documentation went into the preparation. The result is impressive – to put it mildly. This is a veritable encyclopaedia of all the huts erected through the centuries by hunters and trappers in Svalbard. The huts and their foundations are well documented in images both old and new. The sparse text gives the hard facts about each hut: description, history, sources. But it is the photographs that make up the lion's share of the book. And this kind of documentation is particularly important since many of the huts are now in ruins, or only traces of the site remain. This book is destined to become a standard reference work for everyone who is interested in the history of hunting and trapping in Svalbard.

Ann Kristin Balto // Norwegian Polar Institute
Photo: Nils Knaben // Norwegian Polar Institute

Homeward bound

After a foggy summer in North-East Greenland, it's great to be heading home. On the sea crossing to Ålesund, music and dance erupt on board the *Veslekari*. Botanist Per Fredrik Scholander plays the fiddle and preparator Einar Siggeson joins in on the accordion. It's hard to say whether it's the thought of going home that's put these two in party mood or the relief at all the work they've put behind them. Either way, they were clearly having a good time when this photograph was taken!

Six weeks earlier, the *Veslekari* had cast off from the quay in Ålesund, fully manned with a "motley crew". On board were two geologists, a hydrographer, a botanist, a marine zoologist, a zoologist, a taxidermist, an artist, a history professor, and several assistants – all of them led by Adolf Hoel from Norges Svalbard og Ishavsundersøkelser (Norwegian Svalbard and Arctic Ocean Research, which is also the forerunner of the Norwegian Polar Institute). The ship also carried seven hunters, two carpenters, 15 polar dogs and materials for setting up hunting stations and support stations for the company Arktisk Næringsdrift. With 36 men and all their equipment on board, the *Veslekari* was loaded way over the load line.

Despite the vessel lying heavy in the water, the voyage to the island of Jan Mayen went well. When they were nearing Claveringsfjord in northeast Greenland, fog and difficult ice conditions gave them some trouble for the first few days. The fog continued to be a problem over the following weeks, but they avoided it as best they could. It was a busy time in the majestic Greenland fjords, where the men mapped, hunted, and did research, and Norwegian hunting stations sprang up like mushrooms. In the summer of 1930, hunting and support stations were established in as many as 19 places. Equipment was put ashore, and the surplus from the previous hunting year was shipped out. The stations' crews were also replaced.

This was a period when there was a great deal of Norwegian activity in northeastern Greenland, which Norway regarded at that time as no-man's land. On Claveringsøya the geologist Anders Orvin discovered coal deposits, and on 25 July an annexation notice was set up on the island, which said: "The land at K. Stosch is this day annexed by A/S Arktisk Næringsdrift, Oslo, to exploit the coal deposits". This was the first notice of its kind. Two years later, that entire area of Greenland was annexed by Norwegians under the name "Erik the Red's Land", which resulted in the so-called "Greenland case", which Norway subsequently lost at the International Court of Justice at The Hague in 1933.

Projects in the Fram Centre Flagships for 2015

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
A coastal, ice-associated arctic whale in a changing climate	Christian Lydersen	NPI, UiT, NVH, UoW	christian.lydersen@npolar.no
How do a dominant predator and climate shape fish biodiversity over space and time in large marine ecosystems?	Kari Ellingsen	NINA, IMR, UiT, BS, 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, UiT, ApN, NILU, UNIS, UB	borge.moe@nina.no
The coastal migratory behavior of anadromous fish in relation to environmental parameters	Guttorm Christensen	ApN, UiT, NINA, NIVA, FOC, UoWa	guttorm.christensen@akvaplan.niva.no
Impact of harbour seal predation on Tana salmon and Tana salmon fishery	Marius W. Næss	NIKU, NINA, UiT, TRFM	marius.naess@niku.no

Structure, function and change in Arctic and boreal fjord ecosystems

Recovery of coastal kelp ecosystems – driven by climate change or predators?	Hartvig Christie	NIVA, UiT, UoM	Hartvig.christie@niva.no
Region- and stock-specific catch and migration models of Barents Sea salmon	Martin Svenning	NINA, UiT, IMR, UTu, PINRO	martin.svenning@nina.no
Nordic Marine Fjords: Spatial Mapping and Ecosystem Understanding	Lis Lindal Jørgensen	IMR, UiT, ApN, AWI	lis.lindal.joergensen@imr.no
Benthic biodiversity and ecosystem function in Svalbard and North Norway	Sabine Cochrane	ApN, NINA, IMR, UNIS	sabine.cochrane@akvaplan.niva.no
Life on the edge - Blue mussels on Svalbard	Jørgen Berge	UiT, UNIS, ApN, AU, IOPAS, BC	jorgen.berge@uit.no
An integrated approach to understanding weather–ocean interactions along seabird feeding routes	Kjell Einar Erikstad	NINA, IMR, 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, UoM	bodil.bluhm@uit.no
Marine base maps for the Porsanger Fjord	Aivo Lepland	NGU	aivo.lepland@ngu.no
Pelagic ecosystems in ice-covered and ice-free fjords under climate change	Claudia Halsband	ApN, UiT, UNIS	clh@akvaplan.niva.no

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

Sea ice, ecosystems and models

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
SOLICE: Developing Modelling Tools to Understand the Role of Solar Radiation to Sea Ice Mass Balance in a Seasonally Ice Covered Arctic	Mats Granskog	NPI, MET, UiT, ApN, FMI, CRREL, AWI	mats.granskog@npolar.no
Long-term variability and trends in the Atlantic water inflow region (ATWAIN)	Vladimir Pavlov	NPI, IMR, UNIS, UiT, IOPAS, WHOI	vladimir.pavlov@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 (ArctisMod)	Pedro Duarte	NPI, ApN, NIVA, UiT	pedro.duarte@npolar.no

Driving forces and development of new industry

Drivers for Arctic shipping: Transport alternatives, demand for minerals, and supply and demand of Russian icebreakers	Eirik Mikkelsen	NORUT, FNI, ApN, Capia, UAF	Eirik.Mikkelsen@norut.no

Regimes for sustainable management

A-LEX: Regulating Arctic Shipping - Political, technological and environmental challenges	Tore Henriksen	UiT, MarinTek, ApN	tore.henriksen@uit.no

Technology

Ice floe interaction with ships and waves – IfiSaw	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-OASTATE	Agneta Fransson	NPI, NIVA, IMR, UiT, UNIS, BedIn	agneta.fransson@npolar.no
Biogeochemical drivers and climate change on OA -OADRIVERS	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	Caludia 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, IOPAS	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 Ocean acidification	Philip Wallhead	NIVA, IMR	philip.wallhead@niva.no
Population-level effects of Arctic Ocean acidification on copepods	Pedro Duarte	NPI	pedro.duarte@npolar.no
Benthic-pelagic coupling of Arctic Ocean acidification	Evgeny Yakushev	NIVA	evgeny.yakushev@niva.no

Socio-economic consequences and management options

Socio-economic consequences and management options	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
NCoE-Tundra: Herbivore effects on tundra overgrowth, management and environmental gains	Jane Uhd Jepsen	NINA, UiT	jane.jepsen@nina.no
KLIMAVEG: Long term vegetation change in alpine areas in Northern-Norway and Poland – relation to climate and grazing	Jutta Kapfer	NFLI, UiT, UoOu	jutta.kapfer@skogoglandskap.no
Species identification and demographic information from fecal NIRS scans? A study on fox and small rodents	Kari Anne Bråthen	UiT, NINA, NPI	kari.brathen@uit.no

Ecosystem effects of extreme climate events and changing seasons

WINNIT – effects of extreme weather and long distance pollution on plant societies	Jarle W. Bjerke	NINA, Bioforsk, UiT	jarle.werner.bjerke@nina.no
Ecosystem stress from the combined effects of WInter CLimate change and Air Pollution – how do the impacts differ between biomes? (WICLAP)	Jarle W. Bjerke	NINA, MET, NORUT	jarle.werner.bjerke@nina.no
Sentinel Synergy Framework (SenSyF)	Eirik Malnes	NORUT, NINA, UiT	Eirik.Malnes@norut.no
FINEGRASS: Effect of climate extremes on inland production of grass in North-Norway	Gregory Taff	NFLI, Bioforsk, NINA	gta@skogoglandskap.no
SnoEcoPhen: Phenological synchrony of arctic plants and their pollinators at altered snow regimes	Elisabeth Cooper	UiT, UNIS	elisabeth.cooper@uit.no

Capacity for adaptation in indigenous people and local societies

The re-distribution of common winter pastures – a comparative analyses of land tenure privatization (REDISTRIBUTE)	Marius Warg Næss	NIKU, NINA, UCL	marius.naess@niku.no

Adaptive management of ecosystem services

Adaptive goose management beyond borders	Ingunn Tombre	NINA, NIKU, NORUT, AU	ingunn.tombre@nina.no

Observation systems for climate effects

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

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

Climate change impact and new contaminants

RESEARCH AREAS/PROJECT TITLES	PROJECT LEADER	PARTICIPATING INSTITUTIONS	E-MAIL PROJECT LEADER
Climate mediated increases in organic matter export to arctic coastal waters	Amanda Poste	NIVA, ApN, NPI, UiT, UoO, EC, SALT	amanda.poste@niva.no
TraPha- Transformation properties and environmental risk-pharmaceuticals	Roland Kallenborn	NMBU, UNIS, UiT, NILU, NPI, ApN, SRCES RAS	roland.kallenborn@nmbu.no
Influence of pollution and climate variation in rivers and coastal waters indicated by freshwater and marine bivalves (Kolarctic)	Michael Carroll	ApN, Bioforsk, NINA, BC, NHS, UoJ, LCED, TECABN, INEP	michael.carroll@akvaplan.niva.no
Cyclic volatile methyl siloxanes (cVMS) – A case study of Storvatn, Hammerfest	Nicholas Warner	NILU, ApN, UoL	Nicholas.Warner@nilu.no
Uptake and trophic magnification of organophosphorus flame retardants in Arctic lake ecosystems	Anita Evenset	ApN, NIVA, NPI, NILU, UiT	Anita.Evenset@akvaplan.niva.no

Environmental contaminants in a multi-stress perspective

Multi-stress relationships in seabird populations: Interactions between natural stressors and environmental contaminants	Jan O. Bustnes	NINA, NPI, NVH, ApN, NILU, NTNU, CEBC	Jan.Bustnes@nina.no
Effects of contaminant exposure on energetics	Heli Routti	NPI, NILU, UiT, NVH, SINTEF, UoB, UoAa	heli.routti@npolar.no
Impacts of environmental contaminants and natural stressors on northern raptors	Jan O. Bustnes	NINA, NILU, UiT, UoA	Jan.Bustnes@nina.no
Microplastics in arctic marine food chains; biological uptake pathways and socio-economic consequences	Claudia Halsband / Dorte Herzke	ApN, NIVA, NILU, NINA, NORUT, NPI, UNIS, UiT, SALT, TM	claudia.halsband@akvaplan.niva.no dhe@nilu.no
Is the Arctic charr population in Lake Ellasjøen, Bjørnøya, affected by chronic exposure to contaminants?	Anita Evenset	ApN, NIVA, NILU, UiT, CRRLU, UoW	Anita.Evenset@akvaplan.niva.no
Effect of pollution on survival of a top predator: A case study integrating ecotoxicology climatology and demography (TOXICLIM)	Kjell E. Erikstad	NINA, UiT, BS, UoR	Kjell.e.erikstad@nina.no

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

Characterization of new biomarkers of endocrine disruption in *Chlamys islandica*: From natural seasonal baseline levels to their sensitivity towards oil related compounds	Perrine Geraudie	ApN, NILU, IDAEA-CSIC	pge@akvaplan.niva.no
Epigenetic effects of oil pollutants in polar cod	Øivind Andersen	Nofima, ApN	oivind.andersen@nofima.no
Trophic transfer and genotoxicity of PAHs, their alkylated homologues and metabolites along Arctic and sub-arctic marine food chains	Maria Granberg	NPI, ApN, NINA, UiT, NTNU, UoCo	maria.granberg@npolar.no

Human health effects, risk analysis & communication

Contaminants, food and health security in border region	Eldbjørg Heimstad	NILU, NORUT, UiT, ApN, NRPA, FMFI, UoOu, NEI, FMI, NPC, MCBR, INEP	esh@nilu.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
ECOMINA – ECOsystem-based management for areas targeted by deep-sea MINing in the Arctic: A pilot study	Eva Ramirez-Llodra	NIVA, NGU, IMR, UiT, UoS	eva.ramirez@niva.no
Net Environmental Benefit Analysis Tool to Assess the Environmental Effects of Arctic Oil Spills and Oil Spill Response Technologies –NEBA	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 (VULRES)	Raul Primicerio	UiT, IMR, ApN	raul.primicerio@uit.no

Consequences for organisms and ecosystems

Improving Methods to Assess Ecological Restoration in North Norway (EcoRest)	Gregory Taff	NFLI, NINA	gta@skogoglandskap.no
Biological effects of the Skjervøy diesel oil spill – phase II of the sub-Arctic case study	Kjetil Sagerup	ApN, UiT	kjetil.sagerup@akvaplan.niva.no
Mapping and monitoring cultural heritage sites and environments in the Svalbard Archipelago (CULRES)	Stine Barlindhaug	NIKU, NINA, NORUT, NPI	stine.barlindhaug@niku.no
Fate and Impact of MIne Tailings on marine Arctic ecosystems – FIMITA	Anita Evenset	ApN, NGU, IMR, NORUT, NRPA, SIO, UoG	anita.evenset@akvaplan.niva.no
Arctic Cetaceans and Ocean Noise (ACON)	Kit Kovacs	NPI, UiT	kit.kovacs@npolar.no
Mineral Extraction in the High North – Radiological Risks, Impacts and Mitigation (MINEXRIM)	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 (ECOURCHIN)	Wenting Chen	NIVA, UiT, Nofima, UoC	wenting.chen@niva.no
Fragmentation, density dependency and climate change – Saami reindeer husbandry on the brink	Marius Warg Næss	NIKU, NINA, UCL	marius.naess@niku.no
Evaluation of impacts of industrial development on cultural heritage and landscapes within an ecosystem services framework (EvaCES)	Marius Warg Næss	NIKU, UiT	marius.naess@niku.no
Environmental Impact Analyses (EIA) for reindeer herding – an evaluation	Jan Åge Riseth	NORUT, NINA	Jan.Age.Riseth@norut.no

ABBREVIATIONS

ApN: Akvaplan-niva Inc.; **AU:** Aarhus University; **AWI:** Alfred Wegener Institute; **BC:** Bates College; **BedIn:** Bedford Institute; **Bioforsk:** Norwegian Institute for Agricultural and Environmental Research; **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; **CRRL:** Control/Robotics Research Laboratory (NYU Polytechnic School of Engineering); **CRRLU:** Columbia River Research Laboratory USA; **CU:** Clemson University; **DTU:** Technical University of Denmark; **DU:** Dalhousie University; **EC:** Environment Canada; **FMFI:** County governor of Finnmark; **FMI:** Finnish Meteorological Institute; **FNI:** Fridtjof Nansen Institue; **FOC:** Fisheries and Oceans Canada; **FSU:** Florida State University; **JAMSTEC:** Japan Agency for Marine-Earth Science and Technology; **IDAEA-CSIC:** Institute of Environmental Assessment and Water Research – Spanish Council for Scientific Research; **IMR:** Institute of Marine Research; **INEP:** Institute of North Industrial Ecology Problems – Russian Academy of Sciences; **IOPAS:** Institute of Oceanology, Polish Academy of Sciences; **LCED:** Lapland Centre for Economic Development; **MarinTek:** The Norwegian Marine Technology Research Institute; **MCBR:** Murmansk Country Birth Registry; **MET:** The Norwegian Meteorological Institute; **MU:** Massey University; **NEI:** Northern and environmental issues; **NFLI:** The Norwegian Forest and Landscape Institute, **NGU:** Geological Survey of Norway; **NHS:** Natural Heritage Services; **NINA:** Norwegian Institute for Nature Research; **NIKU:** The Norwegian Institute for Cultural Heritage Research; **NILU:** Norwegian Institute for Air Research; **NIVA:** Norwegian Institute for Water Research; **NMBU:** Norwegian University of Life Sciences; **Nofima:** The Norwegian Institute of Food, Fisheries and Aquaculture Research; **NORUT:** Northern Research Institute; **NPC:** The Northwest Public Health Research Center; **NPI:** Norwegian Polar Institute; **NRPA:** Norwegian Radiation Protection Authority; **NTNU:** Norwegian University of Science and Technology; **NVH:** Norwegian School of Veterinary Science; **PINRO:** Polar Research Institute of Marine Fisheries and Oceanography; **RU:** Ryerson University; **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; **TECABN:** Transport and the Environment County Administrative Board of Norrbotten; **TM:** Tromsø Municipality; **TO:** Troms Offshore; **TRFM:** Tana River Fisheries Management; **UAF:** University of Alaska; **UB:** University of Burgundy; **UCL:** University College of London; **UiT:** UiT The Arctic University of Norway; **UoA:** University of Antwerpen; **UoAa:** University of Aalborg; **UoB:** University of Bergen; **UoC:** University of California; **UoCo:** University of Copenhagen; **UNIS:** The University Centre in Svalbard; **UoG:** University of Gent; **UoGo:** University of Gothenburg; **UoH:** University of Hokkaido; **UoJ:** University of Jyväskylä; **UoL:** University of Leicester; **UoLa:** University of Laval; **UoO:** University of Oslo; **UoOu:** University of Oulu; **UoM:** University of Maine; **UoNB:** University of New Brunswick; **UoQ:** University of Queensland; **UoR:** University of Reading; **UoS:** University of Southampton; **UoWa:** University of Waterloo; **UQAR:** Université du Québec à Rimouski; **UT:** University of Texas; **UTu:** University of Turku; **WHOI:** Woods Hole Oceanographic Institution

Recent doctorates

Teena Chauhan

Late Quaternary paleoceanography of the northern continental margin of Svalbard

The thesis reconstructs the variability of Atlantic Water inflow to the Arctic Ocean and its influence on the Svalbard–Barents Sea Ice Sheet (SBIS), sea-ice cover, variations in the bottom current strength and the depositional environment in the past. Two sediment cores were investigated for distribution patterns of planktic and benthic foraminiferal assemblages, stable isotopes in foraminifera, ice-rafted debris, sediment grain size, and organic carbon content. Variable strength of the subsurface Atlantic Water along with insolation has influenced the extent and stability of the SBIS since 132 000 years before present. Distinct increases in freshwater flux during deglaciation periods stratified the upper water column and weakened the ocean circulation, leading to poor sea-bottom ventilation and expanding sea-ice cover. The influence of these "climate drivers" on the local sedimentary and oceanographic environment varied significantly. Regional environmental parameters and feedback mechanisms must thus be considered in reconstructions of the past climate.

Link to the thesis: http://munin.uit.no/handle/10037/8258

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

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

27 August 2015

Firehun Tsige Dullo

Methane gas detection with waveguide interferometers

An optical sensor for measuring methane concentration in air has been developed. Methane is a greenhouse gas and it is important to measure emissions from both man-made and natural sources such as tundra, wetlands and ocean. For this it is necessary to have robust, sensitive and accurate sensors, ideally small enough to deploy on a drone. An ability to measure methane in real time is also desirable. The sensor developed in this project could potentially meet all these requirements. The sensor was tested in the laboratory and provided reproducible results with relatively high sensitivity (17 ppm). The thesis discusses how the sensor can be further developed to measure the methane at natural atmospheric concentrations (1.7 ppm). The sensor has also been implemented for the detection of optically active microparticles.

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

Joint supervision with NORUT Northern Research Institute

10 December 2015

Eythor Gudlaugsson

Modelling the subglacial hydrology of the former Barents Sea Ice Sheet

In this thesis, Gudlaugsson and his colleagues investigate the effect of subglacial water on the evolution of the Fennoscandian and the Barents Sea Ice Sheets. This is done by implementing a thin film model of water flow into an existing numerical ice sheet model and simulating the ice sheet's growth and decay during the last glacial cycle. Additionally, they examine the influence of a subglacial lake on ice dynamics and isochrone layers within the ice. Basal water separates the ice and bed, softens the underlying sediments and leads to a strong increase in ice velocity. Including subglacial hydrology in numerical ice sheet models leads to less ice building up with time during glacial periods and speeds up deglaciation. Subglacial water forms lakes underneath the ice that greatly affect its speed and thermal regime. Lake drainage can result in travelling waves at depth within isochrone layers, indicating the possibility of detecting past drainage events with ice penetrating radar.

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

1 December 2015

Mali Anja Bjerkhaug Hartviksen

Replacement of fishmeal with alternative proteins in diets for Atlantic salmon (*Salmo salar L.*): A study on the microbiota, morphology and function of the intestine

Alternative protein sources influence the intestinal microbiota, morphology and digestive physiology in fish. Little information is available about this in farmed fish. The thesis examines the impact of alternative feed ingredients on the community population and metabolism of intestinal microbiota, their ability to compete with pathogens, fish gut physiology, health, performance and feed utilization. The results indicate a more stable intestinal microbiota than previously reported. Atlantic salmon is able to deal with poorly digestible feed ingredients by increased activity of certain digestive enzymes. Alternative feed ingredients may intensify the damage resulting from exposure to pathogenic bacteria. This damage can be prevented by pre-exposing the intestine to probiotic bacteria. Pea protein concentrate and poultry by-products are useful as fishmeal replacements, whereas soy protein concentrate and sunflower meal should be used with caution due to potentially negative effects.

Link to the thesis: http://munin.uit.no/handle/10037/7874

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

16 June 2015

Simon Pind Jessen

Ice rafting, ocean circulation and glacial activity on the western Svalbard margin 0–74 000 years BP

The thesis builds on 11 sediment cores from circa 600 to 1900 m water depth from the continental slope west of Svalbard and one core from the Barents Sea shelf. The primary goal was to gain a better insight in ocean circulation and glacial activity in a climatic context on glacial-interglacial and millennial time scales. The main findings are that the Svalbard–Barents Sea ice sheet reached the shelf break before 24 000 years BP, when it was at its maximum size. The timing is at least 3000 years earlier than previously reconstructed. The ice sheet was at its largest size for a relatively short time. The millennial scale activity of the Svalbard Barents Sea ice sheet was closely linked to climate change, with a more actively calving ice sheet during warm climate intervals and a stable, probably growing ice sheet during cold climate intervals.

Link to the thesis: http://munin.uit.no/handle/10037/7877

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

Joint supervision with Akvaplan-niva

27 March 2015

Kjersti Julin

Infectious pancreatic necrosis virus (IPNV) - Persistent infections, virulence and antiviral defence

Infectious pancreatic necrosis (IPN) is a fish disease that affects many species world-wide. The virus that causes the disease is infectious pancreatic necrosis virus (IPNV). Carriers of IPNV are free of symptoms and have low or undetectable levels of virus. IPN outbreaks vary widely, ranging from low to high mortality. This thesis describes how molecular differences in field isolates are helping to give the viruses different virulence. A real-time PCR for detection of the VP2 gene was designed for more sensitive detection of virus. When the salmon meets IPNV for the first time the outcome of the infection depends on both the virulence traits of the virus and the effectivity of the innate antiviral immune system of the fish. In this work, researchers have infected smolts in freshwater phase with high and low virulent virus isolates. They have looked at differences in development of disease between virus isolates by measuring the amount of virus and mortality in the sea phase.

Link to the thesis: http://munin.uit.no/handle/10037/7044

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

Joint supervision with NOFIMA

6 February 2015

Jesper Andreas Kuhn

Spatial and temporal variations in parasite communities of freshwater fish in the subarctic

Parasite communities may be affected by many ecological environmental factors, including introduction of host species (as is commonly done in freshwater fish management). This thesis examined spatial and temporal differences in parasite occurrence in Norwegian freshwater fish, and the importance of three-spined stickleback as a parasite transmission host. The parasites in an introduced stickleback population and its nearby source population were highly similar, indicating that moving a host species a short distance will move its parasites as well. *Diphyllobothrium* infections in brown trout were more common in lakes where sticklebacks were present, indicating that stickleback parasites may spread to other fish species. In an unperturbed ecosystem, the intestinal parasite community in arctic char was stable over time and space. Together, these findings suggest that introduction of host species may lead to ecosystem changes and speak against introduction of three-spined stickleback.

Link to the thesis: http://hdl.handle.net/10037/8413

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

3 November 2015

Kjersti Lian

DNA metabolism in extremophiles: Structure-function studies of proteins involved in DNA repair and replication from *Aliivibrio salmonicida* and *Deinococcus radiodurans*

Organisms adapted to cold environments like the deep sea and polar regions have evolved so they can function despite low temperatures. The cold-water bacterium *Deinococcus radiodurans* has a remarkable ability to repair hundreds of DNA breaks – far more than most other bacteria. When infected by bacteria, some species of fish defend themselves by producing oxygen radicals that damage the invader's nucleotides, components of DNA. *Aliivibrio salmonicida* is a fish pathogen that produces the enzyme MutT, which can efficiently remove an oxidatively damaged nucleotide from the nucleotide pool – even at low temperatures. This prevents the oxidized nucleotide from being incorporated into genomic DNA. The thesis investigates in detail the structure and function of enzymes involved in DNA repair and replication in cold-loving species.

Link to the thesis: http://munin.uit.no/handle/10037/8173

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

16 June 2015

Karianne Fredenfeldt Lind

Bioactivity profile of barettin – with special focus on anti-inflammatory, antioxidant and anticoagulant activities

Organisms adapted to extreme environments often contain compounds with unique bioactive properties. This study focused on the compound barettin, isolated from the marine sponge *Geodia barretti,* and its effect on important processes in the development of atherosclerosis. Biochemical and cellular assays showed that barettin had both antioxidant and anti-inflammatory activity: it protected the cell membrane against damage from free radicals, inhibited production of pro-inflammatory cytokines and kinases. It also inhibited production of a chemokine that recruits inflammatory cells involved in formation of atherosclerotic plaques. In addition, it had anti-coagulatory properties. In view of these findings, barettin appears to have potential for drug development.

Link to the thesis: http://munin.uit.no/handle/10037/7906

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

17 April 2015

Mari-Ann Norum Moen

Analysis and interpretation of C-band polarimetric SAR signatures of sea ice

Operational sea ice charts are currently produced manually, an inefficient process resulting in subjective ice charts. This thesis investigates how polarimetric microwave radar signatures relate to the physical properties of sea ice, and how these signatures may contribute to the development of robust automatic algorithms. Our analyses are based on polarimetric space-borne synthetic aperture radar (SAR) scenes and coincident in-situ data. The first analysis revealed major discrepancies between automatically generated and manually drawn ice charts and demonstrated benefits of incorporating polarimetric information into sea ice charting. The second paper explored the transferability of information from one scene to another. The third paper investigated the classification potential of 44 polarimetric features. The best feature subset included six features, achieving a classification accuracy of 70%, reflecting the complexity of the scene.

Link to the thesis: http://munin.uit.no/handle/10037/7049

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

Joint supervision with the Norwegian Polar Institute

16 January 2015

Mohamed Mahmoud Ezat Ahmed Mohamed

North Atlantic–Norwegian Sea exchanges during the past 135,000 years: Evidence from foraminiferal $\Delta^{14}C$, $d^{11}B$, $d^{18}O$, $d^{13}C$, Mg/Ca, and Cd/Ca

Present exchange of surface and deep water between the Arctic Mediterranean Seas and North Atlantic is an important part of the global ocean circulation. In this study, Mohamed and his colleagues studied the exchange of heat and carbon between the North Atlantic and Norwegian Sea over the last 150 000 years. The scientists have reconstructed sea temperature, salinity, carbonate chemistry (pH and CO_2) and looked at the rate of ocean ventilation in the Norwegian Sea and compared it to the northern North Atlantic. Results show that the Norwegian Sea hydrography and its exchanges with the North Atlantic changed in step with regional climate changes in the past. The study provided new insights of how the High Latitude North Atlantic (HLNA) circulation operated during times of rapid melting of ice sheets and a general global warming phase, which may help us predict how the HLNA circulation may operate during the present phase of ice melting and global warming.

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

3 July 2015

Sunil Mundra

Richness and community structure of High Arctic fungi through space and time explored using high-throughput sequencing

Fungi play crucial roles in decomposition, symbiotic interactions, and biogeochemical cycling. Fungi in the High Arctic are finely tuned with both habitats and seasons, but climate change is perturbing this balance. Sunil Mundra investigated fungal species diversity and community structure in Svalbard, using modern sequencing methods. His focus was on fungi associated with the common herb alpine bistort (*Bistorta vivipara*). Fungal community structure varied both spatially and temporally. At broad scales, community structure variation was related to variation in environmental conditions (e.g. temperature, moisture, soil properties). Diversity of root-associated fungi was related to the root size of the host plant and environmental factors, e.g. fewer species in sites with nutrient-poor soil. As snow depth increased the number decomposing fungi species increased, while symbiotic fungi decreased.

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

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

16 December 2015

Martin Alfons Mörsdorf

Effects of local and regional drivers on plant diversity within tundra landscapes

In the tundra, diversity within plant communities is determined by conditions of habitat productivity and ungulate grazing. However, little is known how such conditions modify the difference between communities. Furthermore, diversity patterns may be constrained by the number of available species in a region – the species pool size. Until now, these interactions have not been addressed in tundra. In this thesis, diversity patterns of vascular plant species were assessed in Icelandic tundra valleys and comparable locations in Norway. Plant diversity in Iceland was strongly driven by topography of contrasting landform curvature and elevation, representing different conditions of habitat productivity. Diversity was not affected by current contrasts in sheep grazing. Topography in Norway had similar effects, but the comparison to Iceland indicated that a large species pool size may amplify diversity patterns that are shaped by topography.

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

21 December 2015

Elisabeth Klungerbo Olsen

Bioprospecting of Arctic marine organisms employing bioassay-, chemistry-, and metabolomics-guided isolation

The aim of the thesis was to isolate bioactive marine natural products. Three isolation approaches were studied: bioassay-guided, chemistry-guided and metabolomics-guided. The bioassay-guided approach yielded an antioxidant, bromophenol, from the alga *Vertebrata lanosa*. Bromophenol was active in both biochemical and cellular assays. Chemistry-guided isolation yielded two brominated indoles, structurally similar to the known bioactive compound barettin, from the sponge *Geodia barretti*. These indoles were used as inspiration for synthesising a library of 22 structurally similar compounds. Synthetic compounds that had a bromine substituent in a specific structural position along with a positively charged amine were most potent. The brominated indoles were however less potent as acetylcholine esterase inhibitors than barettin and 8,9-dihydrobarettin. Metabolomics-guided isolation was used to study differences in natural products produced by *G. barretti and G. macandrewii.*

Link to the thesis: http://munin.uit.no/handle/10037/8145

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

25 September 2015

Irene Dorothea Pathirana

Holocene primary productivity variability in the western Barents Sea – A multi-proxy geochemical approach coupled with organic-facies modelling

The thesis aims to investigate the effects of environmental changes in the Arctic versus flux, conservation and accumulation of organic carbon in the Barents Sea over the last 6000 years. This is done by examining the production of organic matter in the water column and its fate in the sediments at the regional level and thus demonstrates the potential for carbon storage in the Barents Sea. The results show that modern primary production rates, reconstructed from marine organic matter stored in the sediment, are highest at the ice edge in the Barents Sea. Primary production rates of the past 6000 years reconstructed from sediment cores from the northern winter ice-covered Barents Sea are more variable and generally higher than in the ice-free south, where they have remained relatively stable during the Holocene. The results suggest that first-year ice is a necessary prerequisite for potential carbon storage in the Arctic.

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

30 October 2015

Kristine Bondo Pedersen

Applying multivariate analysis to developing electrodialytic remediation of harbour sediments from arctic locations

Pedersen worked with the development of a method for removing pollutants from contaminated harbour sediments in the Arctic in northern Norway, Greenland and Russia. She applied an electric field to the sediment, mobilising and removing pollutants from the sediments by electrodialysis. The remediation efficiency proved to be dependent on the type of sediment. Grain size, the chemical composition of the pollutant, and how pollutants were bound in the sediment were among the most important characteristics for the removal. Pedersen found that the various pollutants required different conditions for effective purification. She concludes that it is possible to remove heavy metals and some organic pollutants to acceptable levels and believes the electrodialytic remediation method has potential for increasing the future re-use of harbour sediments.

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

13 March 2015

Alexey Portnov

Role of subsea permafrost and gas hydrate in postglacial Arctic methane releases

The greenhouse gas methane is contained in the ice-like structure gas hydrate present in enormous amounts under the seabed in Arctic regions, including the West Svalbard continental margin. In the Russian Kara Sea, the subsea permafrost is acting as a cap, postponing release of the gas to the future. Nonetheless, continuous expulsions of methane have been already observed in both places. This study shows how the subsea permafrost in the Kara Sea, and gas hydrate systems offshore West Svalbard, have evolved from the last ice age to the present day. Portnov concludes that that continuous permafrost of the Kara Sea is more fragile than previously thought. Offshore Svalbard, almost 2000 active and inactive gas expulsion sites are associated with melting of gas hydrate and thawing of shallow permafrost from past to present. The study shows that natural climate drivers such as methane release can change and that they are connected to the ice sheet retreat since the last ice age.

Link to the thesis: http://munin.uit.no/handle/10037/8220

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

18 September 2015

Virginie Ramasco

Spatial and temporal patterns of foraging of harbour seals (*Phoca vitulina*) in Porsangerfjord: from behavioural interpretation to resource selection.

The coastal cod stock of Porsangerfjord declined drastically in the 1980's and never fully recovered. A population of harbour seals, resident in the fjord all year round, has been hypothesised to affect the lack of recovery of cod. In order to understand their role in this ecosystem, the movement patterns of fifteen individual harbour seals were followed and their foraging behaviour investigated by assessing their preference for certain prey types and their behavioural response to the seasonal dynamics of prey distribution in the fjord. Results indicated that harbour seals in Porsangerfjord preferred small fish (< 25 cm), especially small pelagic fish when these aggregated near the seals' haul out sites to overwinter. Otherwise small cod were preferred. The effect of harbor seals feeding on cod in Porsangerfjord can therefore be assumed to decline with increased availability of aggregated pelagic fish during the winter and spring seasons.

Link to the thesis: http://munin.uit.no/handle/10037/8149

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

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

24 September 2015

Srikumar Roy

Geological controls on fluid flow and seepage in western Svalbard fjords

Through systematic mapping of pockmarks (seepage features on the seafloor) and various submarine landforms, Srikumar Roy found that pockmarks are aligned along seafloor ridges in several parts of Isfjorden, in Svalbard. His research established a linkage between these seafloor ridges and thrust faults. His findings suggest that tectonic features of the West Spitsbergen fold-and-thrust belt facilitate migration of fluids from deeper stratigraphy to the seafloor. He also analysed the cause–effect relationship between pockmarks and submarine debris lobes. Subsurface acoustic features identified in the marine sediments of Grønfjorden, inner Isfjorden and Nordfjorden, may indicate presence of shallow gas in the marine sediments. The seepage and fluid flow characterisation done in inner Isfjorden contributes to the marine baseline study for the UNIS CO_2 lab, a pilot project on carbon dioxide storage, in which CO_2 may be injected in the Upper Triassic–Middle Jurassic Kapp Toscana Group aquifer.

University of Bergen
Faculty of Mathematics and Natural Sciences
Department of Earth Science

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

6 November 2015

Faozi Said

On the generalized curvature ocean surface scattering model for the NRCS and doppler frequency and its application to ocean surface wind retrieval from Synthetic Aperture Radar data

Ocean wind monitoring is an integral part of weather forecasting, maritime shipping lane planning, offshore wind research, as well as the study of climate patterns. Satellite radar instruments, such as Synthetic Aperture Radars (SAR), can help achieve this important task by monitoring the wind conditions over the sea surface. Using specially developed functions, called geophysical model functions, wind speed and direction can be inferred from the radar measurements. This thesis presents an alternative approach using two key parameters from the SAR instruments to infer wind measurements from SAR data. The procedure is made possible using both backscatter and Doppler models based on an electromagnetic scattering model developed by Geir Engen, Ida Friestad-Pedersen, Harald Johnsen, and Tanos Elfouhaily. The researchers also revisit and improve these two geophysical model functions by including a more realistic description of the sea surface.

Link to the thesis: http://munin.uit.no/handle/10037/7876

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

Joint supervision with NORUT Northern Research Institute

23 January 2015

Heïdi Sevestre

Surge-type glaciers: controls, processes, distribution

Surge-type glaciers regularly undergo long periods of slow flow, and short periods of extremely rapid flow, the surge. In Svalbard, up to 20% of the glaciers are surge-type, vs 1-2% worldwide. Heïdi Sevestre uncovered differences in glacier distribution and geometry: surge-type glaciers are found in specific climatic conditions and are larger, flatter and branchier than normal glaciers. These patterns are interpreted in new conceptual framework, the enthalpy cycle model. The surge mechanisms of Svalbard glaciers were also tested by mapping the thermal structure of six glaciers of different sizes and dynamics. Presently cold and thin glaciers underwent a thermal cycle during the Little Ice Age maximum, yielding a corresponding switch in behaviour. Large surge-type glaciers remain warm-based during quiescence, demonstrating that thermal switch is not the trigger to surging. The chronology of two surges in Svalbard was also investigated in detail.

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

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

13 October 2015

Jennifer Stien

Nest predation in birds of conservation concern. Case studies of monitoring and management

Stien used a variety of methods at different spatial and temporal scales to explore population processes and management of two bird species of conservation concern, focusing particularly on the role of nest predation in declining populations. She has demonstrated the role of proximate and ultimate causes of nest loss in common eider at two declining colonies, highlighting the negative effects of human disturbance on nesting success and the potential role of disturbance in the decline at one of the colonies. Stien also demonstrates the usefulness of combining investigation of the regional decline of Slavonian grebe with the targeted alien invasive species, American mink. Finally, she shows that collaborative control programs that include volunteer mink hunters are best focused on hotspots of conservation concern. This adaptive protocol approach can be undertaken with relatively little funding and resource use and is simple in its design.

Link to the thesis: http://munin.uit.no/handle/10037/7875

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

12 June 2015

Kristoffer Svendsen

Compensable damage ex delicto as a result of harm in the Barents Sea caused by petroleum spills from offshore installations. A Norwegian and Russian comparative legal analysis of conflict of laws, the concept of harm, losses suffered by third parties, and environmental damage and its valuation and calculation, caused by petroleum spills from offshore oil rigs and installations in the Barents Sea

The dissertation treats some procedural and material aspects of liability for pollution damage from oil platforms in the Barents Sea. The thesis deals with Norwegian and Russian law of damages and compares these two legal systems focusing on transboundary pollution damage from either Norwegian or Russian shelf of Norwegian or Russian side of the dividing line.

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

4 September 2015

Ding Tao

Maritime target detection in non-homogeneous sea clutter environments based on single- and multi-polarization Synthetic Aperture Radar Data

This thesis studies the subject of maritime target detection using synthetic aperture radar (SAR). In real maritime surveillance and monitoring systems, an advanced operational target detector is a key component and must be able to work in unknown target situations and under various non-homogeneous sea surface conditions. In this study, truncated statistics and a modified segmentation stage are adopted in the constant false alarm rate (CFAR) detection scheme, which is proved to be an optimal solution to simultaneously address the frequently encountered detection issues, i.e., the capture effect in multiple-target situations, and the clutter edge effect due to meteorological and oceanographic phenomena. Compared to the conventional CFAR detectors, the proposed target detection algorithm is able to operate in various contaminated non-homogeneous environments, provide rigorous statistical analysis of local background clutter, and deliver improved robust detection performance.

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

3 December 2015

Mikko Juhani Vihtakari

Bivalves as indicators of environmental perturbations related to climate and ocean acidification

The thesis examined susceptibility of bivalves to environmental perturbations and usage of bivalve shells as sub-annual environmental proxy archives. This was done in two experimental settings: 1) ocean acidification (OA) experiments on bivalve gametes and early larval stages, and 2) year-long bivalve deployments on oceanographic moorings in two Svalbard fjords followed by geochemical sampling of bivalve shells. *Mytilus* larvae were sensitive to ocean acidification, but global warming might have an even larger impact. The high-end OA scenarios for 2100 reduced sperm activity of *Mytilus galloprovincialis*, likely reducing fertilisation success in low-density populations. Individual males have different tolerances to OA, indicating that *Mytilus* populations can adapt to moderate reductions in ocean pH. Shell growth rate of *Serripes groenlandicus* and *Ciliatocardium ciliatum* correlated with temperature. The length of the growth season was determined by food availability.

Link to the thesis: http://munin.uit.no/handle/10037/7152

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

Joint supervision with the Norwegian Polar Institute and Akvaplan-niva

13 March 2015

Ole Petter Laksforsmo Vindstad

Cyclically outbreaking geometrid moths in sub-arctic mountain birch forest: the organization and impacts of their interactions with animal communities

Outbreaks of herbivorous geometrid moths periodically cause mortality of enormous areas of mountain birch forest in northern Scandinavia. The ecological consequences of these outbreaks are relatively little known. Part of the goal of this PhD project was to investigate the short-term effects of outbreak-induced forest mortality on communities of passerine birds and wood-decaying beetles. Both groups appeared to be relatively little affected by forest mortality, suggesting a high degree of resistance to such disturbance. Another goal of the project was to gain a better understanding of the functioning of one of the most important enemy communities of geometrid moths, namely parasitoid wasps. The project concluded that different species of parasitoid have similar capacity for inflicting parasitism on moth populations. This will cause parasitism rates to be less affected by variation in parasitoid species-composition in space and time.

Link to the thesis: http://munin.uit.no/handle/10037/7004

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

Joint supervision with the Norwegian Institute for Nature Research.

9 January 2015

Ingrid Wiedmann

Potential drivers of the downward carbon and particle flux in Arctic marine ecosystems under contrasting hydrographical and ecological situations

Detailed predictions of the downward particulate organic carbon (POC) flux in future Arctic marine ecosystems are challenging due to the poor understanding of potential drivers of the flux. Short-term sediment traps, partly modified with gel-containing jars (gel traps), were deployed in the Barents Sea and in Adventfjorden, Svalbard, to determine the downward POC flux and the particle flux (≥ 0.05 mm equivalent spherical diameter ESD_{image}). In this way, it could be illustrated that a high downward POC flux in Arctic marine ecosystems may not only occur during the phytoplankton bloom, but can also be found in deep-mixed waters in the southern Barents Sea during a post bloom situation or during an autumn situation in an Arctic fjord influenced by glacial run-off. The study further points out that a high POC downward flux is not necessarily caused by large particles, but may also occur in form of small particles with a high POC:volume ratio.

Link to the thesis: http://munin.uit.no/handle/10037/8293

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

Department of Arctic and Marine Biology

13 November 2015

Contact information

FRAM – the High North Research Centre for Climate and the Environment

Fram Centre AS
Ph: +47 7775 02 00

Fram Institutions at the Fram Centre building
Visiting address: Hjalmar Johansens gate 14
Postal address: POB 6606 Langnes
N-9296 Tromsø
Ph: +47 7775 0200
Web: www.framsenteret.no

Fram Centre information portal:
www.iframe.no
Videos: framshorts.com

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

Geological Survey of Norway
Ph: +47 7775 0125
www.ngu.no

Norwegian Coastal Administration
Ph: 07 847, International calls +47 3303 4308
www.kystverket.no

NILU – Norwegian Institute for Air Research
Ph: +47 6389 8000
www.nilu.no

Norwegian Institute for Cultural Heritage Research
Ph: +47 7775 0400
niku.no

Norwegian Institute for Nature Research
Ph: +47 7775 0400
nina.no

Norwegian Mapping Authority Tromsø
Ph: 08 700, International calls +47 3211 8121
www.statkart.no

Norwegian Polar Institute
Ph: +47 7775 0500
www.npolar.no

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

FRAM institutions elsewhere

CICERO – Center for International Climate and Environmental Research
Ph: +47 2285 8750
www.cicero.uio.no

Institute of Marine Research Tromsø
POB 6404, N-9294 Tromsø
Ph: +47 5523 8500
www.imr.no

NOFIMA
Muninbakken 9-13 Breivika
POB 6122, N-9291 Tromsø
Ph: +47 7762 9000
www.nofima.no

NIBIO
Norwegian Institute of Bioeconomy Research
POB 2284 Tromsø postterminal, N-9269 Tromsø
Ph: 03 246, International calls: +47 4060 4100
www.nibio.no

NORUT Northern Research Institute
www.norut.no

> **NORUT Tromsø**
> POB 6434 Forskningsparken, N-9294 Tromsø
> Ph: +47 7762 9400 Fax: +47 7762 9401
> www.norut.no/tromso
>
> **NORUT Alta**
> POB 1463, N-9506 Alta
> Ph: +47 7845 7100
> www.norut.no/alta
>
> **NORUT Narvik**
> POB 250, N-8504 Narvik
> Ph: +47 7696 5350
> www.norut.no/narvik

NORINNOVA Northern Innovation
POB 6413 Forskningsparken, N-9294 Tromsø
Ph: +47 7767 9760
www.norinnova.no

Norwegian Meteorological Institute
Main office: Henrik Mohns plass 1, N-0310 Oslo
Forecasting Division of Northern Norway
Kirkegårdsveien 60, N-9293 Tromsø
Ph: +47 7762 1 00
met.no

Norwegian School of Veterinary Science
Dept. of Arctic Veterinary Medicine
Stakkevollveien 23, N-9010 Tromsø
Ph: +47 7766 5400
www.veths.no

Norwegian Veterinary Institute
Stakkevollveien 23, N-9010 Tromsø
Ph: +47 7761 9230
www.vetinst.no

NMBU
Norwegian University of Life Sciences
P.O. Box 5003, N-1432 Ås
Ph: +47 6723 0000
www.nmbu.no

SINTEF Nord AS
POB 118, N-9252 Tromsø
Ph: +47 7359 3000
www.sintef.no

University Centre in Svalbard (UNIS)
POB 156, N-9171 Longyearbyen
Ph: +47 7902 3300
www.unis.no

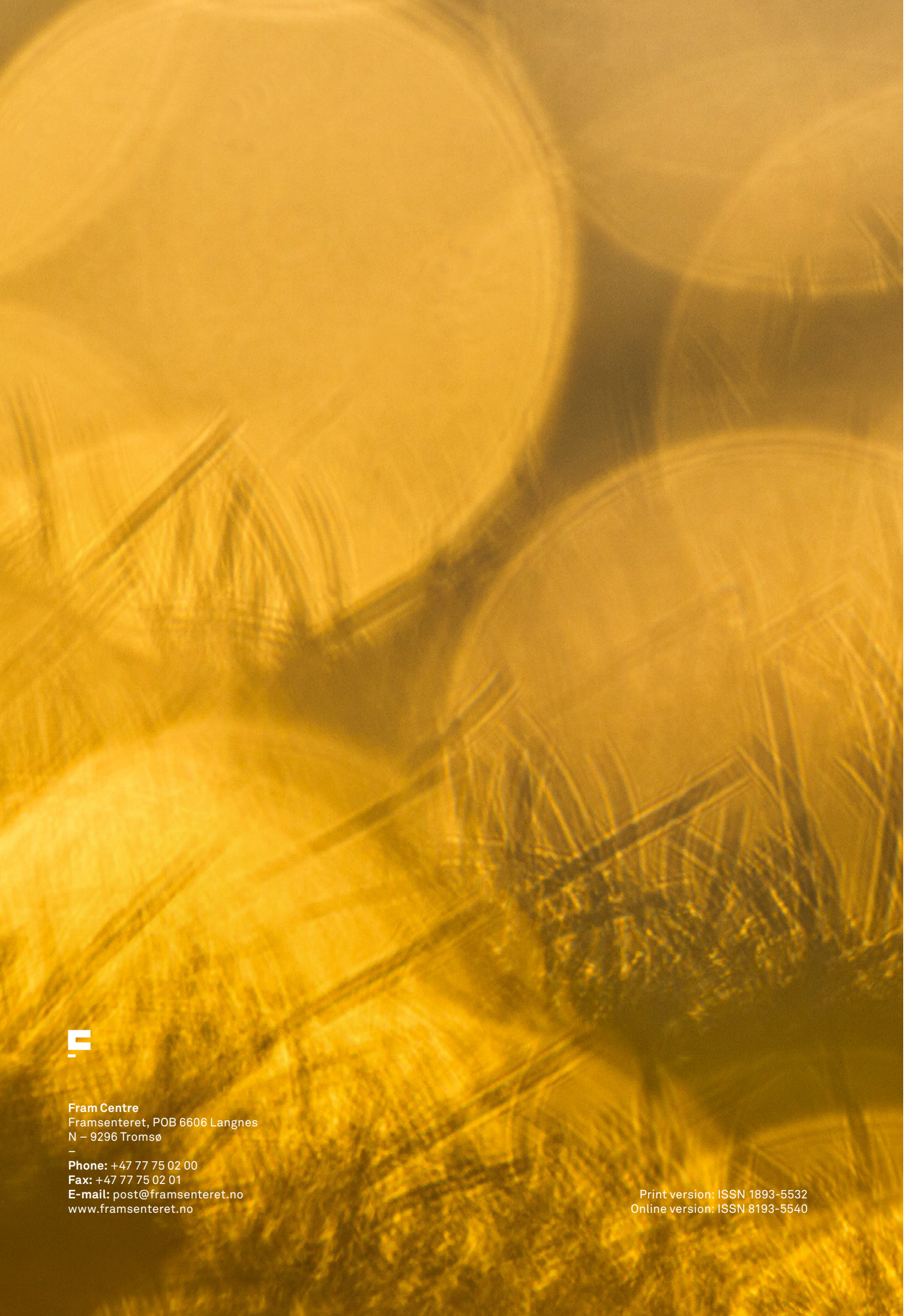
UiT The Arctic University of Norway
N-9037 Tromsø
Ph: +47 7764 4000
uit.no

Other institutions at the Fram Centre

Arctic Council Secretariat
Ph: +47 7775 0140
arctic-council.org

CliC International Project Office
Ph: +47 7775 0150
www.climate-cryosphere.org

Polaria Visitors' Centre
Hjalmar Johansens gate 12, N-9296 Tromsø
Ph: +47 7775 0100
www.polaria.no



Fram Centre
Framsenteret, POB 6606 Langnes
N – 9296 Tromsø
–
Phone: +47 77 75 02 00
Fax: +47 77 75 02 01
E-mail: post@framsenteret.no
www.framsenteret.no

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