the Nansen LEGACY

Annual report
2020


The Nansen Legacy Report Series 18/2021

The Nansen Legacy

Annual Report 2020

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Statement from the Board

The Nansen Legacy project may be compared to a large ship. It takes time to get to the cruising speed, and abrupt maneuvers may be challenging. In 2020, the Nansen Legacy experienced both. At the start of the year, the more than 200 project participating scientists and supporting functions across generations, institutions and disciplines, were prepared for a year with comprehensive activities in the field, at conferences, in workshops, around mobility and PhD courses.

Then came the COVID-19 pandemic in March, requiring a change in the planned route for all. Through collaborative efforts, a dedicated will and ability to find new opportunities and solutions, the project members, administration and partner institutions were able to move the project as a whole and the small subunits forward. The results can be seen in the present report, and we are very pleased with the ability of the project leadership and participants to adapt to the realities of the pandemic. A high activity level and many scientific results were achieved despite the numerous maneuvers needed to adhere to the special circumstances of the pandemic.

A successful mooring service during autumn facilitated collection of valuable datasets in the northern Barents Sea through the last year, when institutions, research vessels and manpower experienced lock downs. Combined with remote sensing and tests improving the AUV under ice operations, this illustrates how the field of technology can provide data also from Arctic locations at a reduced risk and cost at present and in the future.

The combined efforts across institutions have been key to adapt to the changes and to explore new possibilities. Digital solutions have opened for broader participation in webinars and has stimulated to build new collaborations and perspectives. The project participants have expanded their toolboxes with additional platforms that will help them reach the more holistic understanding of the climate and ecosystem that is aimed for, to provide the society with the necessary knowledge for a sustainable management.

The cancelled travels and meetings provided the additional funding needed for COVID-adapted Arctic fieldwork in 2021. The highest price of the abrupt maneuvers and slowed down speed has been paid by the early career scientists with short contracts, tighter schedules, less well-equipped home offices, and their worries for missing opportunities to establish and strengthen the international network they need to build for their future career development in science. ■

Photo: Rudi Caeyers

The Nansen Legacy – steady sailing in troubled waters

From left to right: PI Marit Reigstad, co-PI's Tor Eldevik and Sebastian Gerland.
Photo: Magne Velle

The Nansen Legacy project set sail in 2018. By breaking ice we have been sailing steady ahead, despite the challenges of 2020. The broader Nansen Legacy horizon is now slowly emerging. Halfway into our six-year voyage, an increasing number of publications adds both specialized and more integrative pieces to the puzzle of understanding the physical environment and climate of the Barents Sea, how the ecosystem responds, and what the future may hold.

The Gulf Stream's northernmost limb carries substantial amounts of heat poleward and plays a key role in regulating the environmental conditions in the Barents Sea and beyond. Our recently published research reveals how, e.g., presently reduced heat loss to the atmosphere in the southern Barents Sea results in warmer water now entering the adjacent Nansen Basin, weakening stratification.

Ongoing rapid melting of sea ice north of Svalbard is also explained by warm Atlantic inflow combined with increased mixing from storms in recently ice-free waters. Zooming out, we find that winter cyclones reaching the Barents Sea, are linked to large-scale atmospheric conditions rather than local sea ice conditions. This illustrates how an understanding of the changing Barents Sea requires a larger geographic scope, involving both ocean and atmosphere research.

The increasing Atlantic influence increases the number of boreal species in the Arctic region of the Barents Sea. The boreal species change the structure as well as the interactions in the Arctic food webs.

Timeseries data show that increased water temperatures and reduced sea ice conditions increase individual growth for Polar cod, but weaken the overall recruitment to the early year classes resulting in reduced stock abundance. This contrasts the more boreal species that increase their recruitment under these conditions.

An evaluation of the potential effect of using balanced harvesting as a new management tool in the Barents Sea shows that the existing harvest strategy is estimated to be close to optimal for our present target species.

At the end of the third year of the Nansen Legacy project, 71 early career scientists are now hands-on in the project work. You can read more about who they are and where they come from in this annual report. To integrate knowledge across disciplines, two dedicated PhD courses have brought recruits and teachers together to focus on Arctic Ocean functioning and Arctic Ocean biogeochemistry. A third course on best practices for multifactor experiments was held in collaboration with the Scientific Committee on Oceanic Research (SCOR).

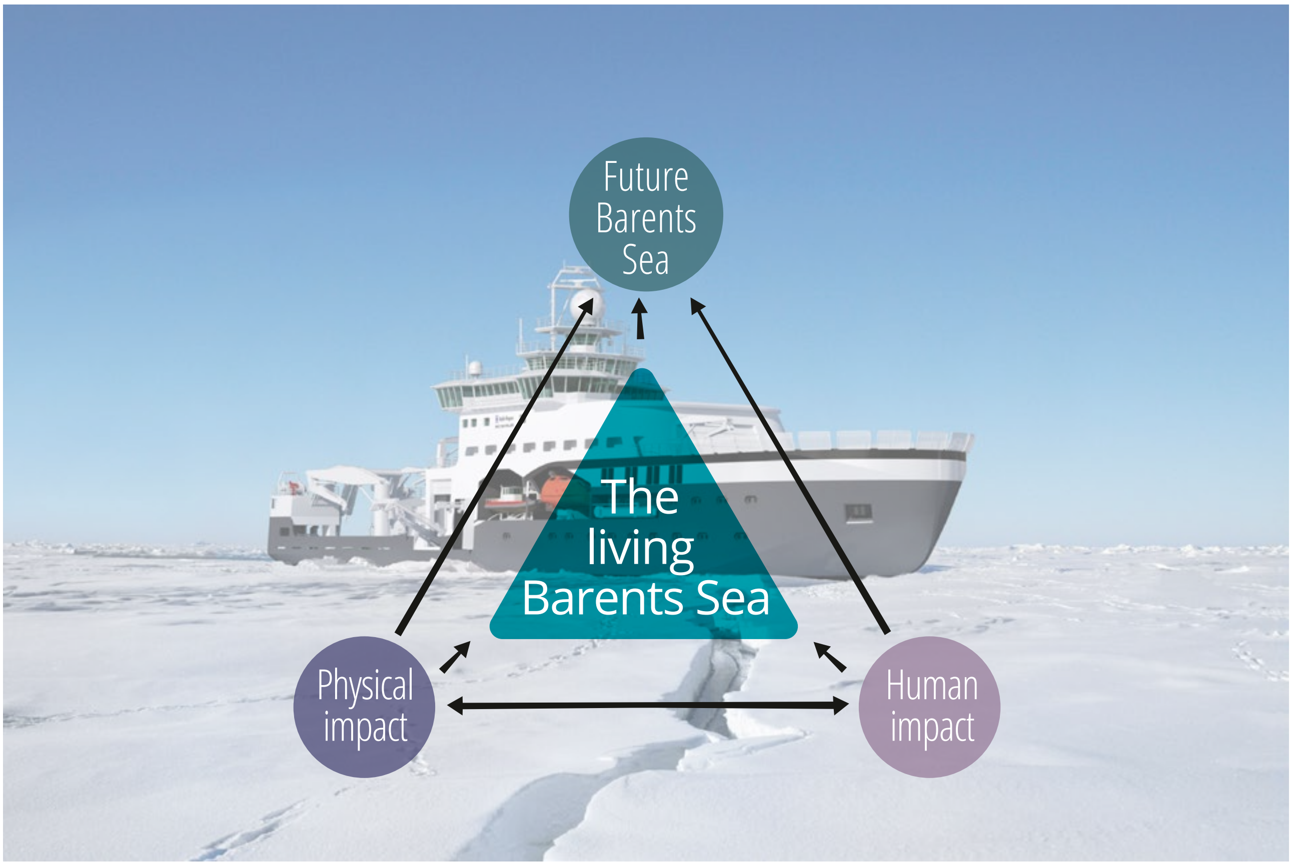
On the topic of more public interaction, the start of 2020 included two side events during the Arctic Frontiers conference with scientists and members from the Nansen Legacy reference group. There were discussions on how we move from science to useful knowledge, and on fisheries management in a changing Arctic Ocean. Project members have also been involved in the advice and debate relating to the Norwegian government updating the environmental and geographical criteria (the regulatory "ice edge") for managing the Barents Sea and implications for the future; in the upcoming IPCC assessment report; and in suggesting fields of priority for Norway during the UN decade of ocean science and development for sustainability.

Despite steady sailing project-wise, the waters we encountered in 2020 were far from clear. First, guarantee work on our new ice breaking research vessel became more extensive than planned and led to the cancelation of our first planned cruise. Then came the COVID-19 pandemic that caused the shutdown of all arctic fieldwork. Our work places were closed, planned analysis and lab work postponed, travels to conferences and mobility for early career scientists had to be postponed or cancelled, meetings and workshops were moved to digital platforms.

The entire project had to adjust to activities that could be run from home offices and nearby field locations. As project PIs we have been impressed by the efforts and ability to adapt by using models and historic data, twists to use local environment for small scale process studies, and tests of new technological solutions. While still facing a pandemic situation at the start of 2021, we are presently catching up nicely on the postponed fieldwork.

All in all, and despite some troubled waters, the Nansen Legacy and its participants have made great progress in 2020 thanks to the collaborative spirit combined with individual and institutional dedication across the entire project. ■

Vision and objectives



The four research foci of the Nansen Legacy. Physical and human impacts on the living Barents Sea will determine the state of the future Barents Sea.
Illustration: Tor Eldevik, Rudi Caeyers

The Nansen Legacy is a novel and holistic Arctic research project. It provides integrated scientific knowledge for sustainable management of the marine environment and resources of the Barents Sea and adjacent Arctic Basin through the 21th century. The Nansen Legacy has the following objectives:

1. Improve the scientific basis for sustainable management of natural resources beyond the present ice edge
2. Characterize the main human impacts, physical drivers, and intrinsic operations of the changing Barents Sea ecosystems in the past, present and future
3. Explore and exploit the prognostic mechanisms governing weather, climate and ecosystem, including predictive capabilities and constraining uncertainties
4. Optimize the use of emerging technologies, logistic capabilities, research recruitment and stakeholder interaction to explore and manage the emerging Arctic Ocean

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An upward looking ADCP is prepared for deployment. The instrument will sit at the bottom of the Barents Sea and measure the speed and direction of ocean currents.
Photo: Ragnheid Skogseth

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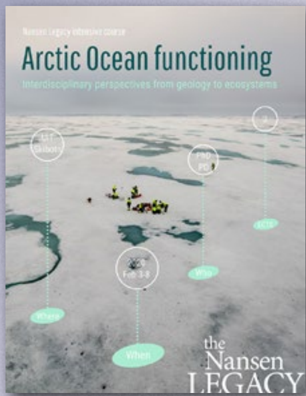
2020 in brief

Arctic Frontiers Side events
During the Arctic Frontiers conference in January, the project organized two side events to enhance the dialogue with users and stakeholders.



PhD intensive course
The first Nansen Legacy interdisciplinary intensive course was held at UiT's field station in Skibotn one week in February. The course was attended by 18 PhD and postdoctoral fellows.

Harmonizing metabarcoding analyses
Making sampling and data analysis efforts coherent between scientists from different institutions is an important effort within the project. In February, a four-day long workshop was organized to develop a common practice on metabarcoding analyses.

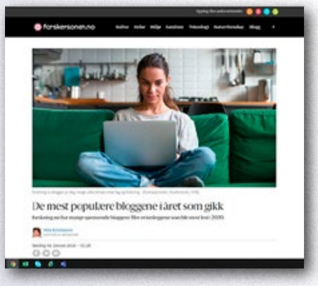
Position of the ice edge
During spring, the Norwegian government decided on the position of the ice edge in the Barents Sea, with implications for the potential exploitation of the region. Nansen Legacy scientists presented updated knowledge and scenarios prior to the discussion on where to place the ice edge.

January

Nansen Legacy on TV
In January, the Norwegian TV channel NRK launched the documentary series 'SnowHow', which also features Nansen Legacy research and field work in August 2018. The series was later also broadcasted in Denmark and Germany.

Contributing to the IPCC Sixth Assessment Report
In spring 2020, the second order draft of the working group 1 report was reviewed by governments and experts. Several Nansen Legacy scientists contributed to the draft.

Conference contributions
The Nansen Legacy was with 23 oral and 9 poster presentations well represented at leading international science conferences, such as e.g. the Ocean Sciences, the EGU or IEEE meeting in 2020.



Project blog
In May, the project posted a blog post which should become one of the ten most red on sciencenorway.no and forskning.no in 2020. The blog text also made it to a US American science news side.

Individual dialogue meetings with users
In order to strengthen the dialogue on specific topics, the project conducts individual dialogue meetings with interested users, and met with AMAP in February.

UN decade of ocean science
The Nansen Legacy participated in the expert panel suggesting Norway's priorities during the decade for ocean science for sustainable development.

Postponed Physical process cruise and Seasonal study 1. quartal cruise to 2021 due to required and extended guarantee work on RV *Kronprins Haakon*.

Cancelled collaborative sampling efforts with MOSAiC due to postponed cruises and cancelled accompanying flight campaigns.

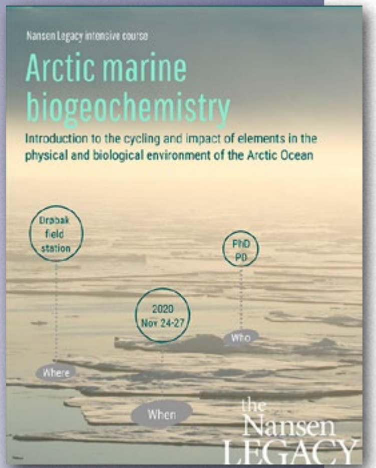
Postponed Seasonal study 2. quartal cruise to 2021 due to COVID-19 restrictions.

Postponed Nansen Legacy/ ARCTOS PhD course cruise to the Polar Front to 2021 due to COVID-19 restrictions.

Alternative field work
The postponement of cruises led to individual alternative field plans, either joining other research cruises to the Barents Sea, or by collecting material closer to home in a fjord close to Tromsø.

Multi-factor experiments
Together with the ARCTOS network and the SCOR Working Group 149, the Nansen Legacy held a one-day course on multi-factor experiments in marine sciences.

Annual project meeting
A digital annual meeting was held in November. Up to 160 people participated in the three-day long meeting consisting of scientific presentations, panel debates, and workshops.



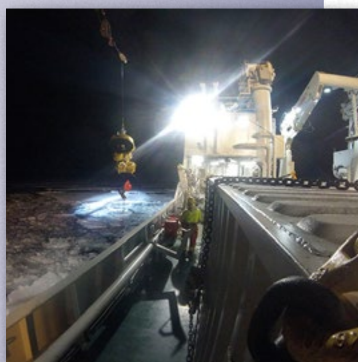
PhD intensive course
This four-day long intensive course addressed Arctic marine biogeochemistry. In total 13 PhD and postdoctoral fellows joined the digital course in November.

December

Webinars
To compensate for the limited possibilities to meet in person during the lockdown, the Nansen Legacy increasingly used webinars to highlight and discuss topics of interest.

Science for kids
In fall, Nansen Legacy scientists met pre-school and school kids to convey basic knowledge about Arctic marine ecosystems, and how to conduct own research.

Paleo-workshop
In 2018, the project retrieved 96 multicores, 23 gravity cores and 6 piston cores for paleo-oceanographic studies of the northern Barents Sea. A digital workshop allowed scientists from inside and outside the project to discuss and test different age models for coherent analyses of the cores.



Mooring service and physical process cruise
The cruise focused on ocean mixing and water transformation processes in the region east of Svalbard, with particular focus on the Barents Sea Polar Front region.

Postponed analyses of field samples due to closed laboratories because of the COVID-19 pandemic.

Postponed or cancelled mobility and planned stays abroad due to COVID-19 induced travel restrictions.

Cancellation of all physical workshops for cross-institutional work due to COVID-19 restrictions.

Cancellation of the annual Nansen Legacy Recruit Forum due to sudden re-implementation of travel restrictions.

Photo: Christian Morel / christianmorel.net

Barents Sea cooling machine slowing down?

Refrigerators are cooled by heat pumps, which transfer heat from the refrigerator's inside to the outside environment. That way, the refrigerator's inside is cooled to a temperature below room temperature. A similar mechanism makes the Barents Sea one of the worlds' largest refrigerators. But how stable is the Barents Sea cooling machine? Can it break down as the fridges in our kitchens, and does it matter?

The global ocean conveyor belt

To answer this question, you need to understand how the Barents Sea is part of a global ocean circulation, the Atlantic Meridional Overturning Circulation (AMOC). The AMOC consists of two "limbs" of ocean currents: one northward flowing, warm and salty in the surface, and one southward flowing, colder current in the deep. The AMOC is an important component of the Earth's climate system.

Small and shallow not necessarily a bad thing

The two "limbs" of the AMOC are linked near the poles, where warm surface water is cooled and plunges into the deep, feeding the deep flowing cold current. Most of the overturning on the Arctic side of the conveyor belt, takes place in the Nordic and Labrador Seas. Despite its small size, also the Barents Sea plays a relatively big role in this process. This is where the refrigerator comes into the story.

The Barents Sea cooling machine

Warm Atlantic Water (AW) flows into the Barents Sea between Norway and Spitsbergen. On its way through the shallow Barents Sea low air temperatures cause a cooling of the AW, which transforms AW into Barents Sea Water (BSW). As such, it reaches the sea ice. The sea ice closes a lid over the water and stops it from further cooling by the air. Since cold and salty water is denser than fresh and cold water, the AW slips beneath the fresher surface water under the sea ice (fresh due to ice melt), plunges into the deep and exits the Barents Sea to the north, into the Arctic Ocean. Here, it circulates and finally joins the overflow waters from the Nordic Seas that feed into the AMOC. A particularity of the Barents Sea cooling machine is that it has a positive feedback loop. That is, if more or warmer AW enters the Barents Sea, sea ice is reduced. This leads to more ocean heat lost to the atmosphere, resulting in more BSW exiting the Barents Sea into the Arctic Ocean. This again strengthens the deep cold water "limb" of the AMOC and the Earth climate system.

Ocean feedback loop about to change?

In a recent study, Nansen Legacy researcher Øystein Skagseth (IMR) and co-authors, compared hydrographic observations from a cold period (1985-1999) to a warm period (2004-2018) in the Barents Sea. The results indicate that less cooling took place in the Barents Sea in the warmer period, contradicting the mechanism described above. However, the observed reduced cooling is attributed to the domination of unusual southerly winds, leading to warmer air temperatures and thus less cooling. Hence, the water exiting the Barents Sea has become warmer but is still salty and dense enough to plunge as BSW into the Arctic Ocean. However, that may change in the near future, as a fresh anomaly has been observed upstream in the AW in 2017/2018 and is expected to propagate into the Barents Sea in the years to come. Then the export water might no longer be dense enough to plunge. ■

> "Under the assumption that the recent reduced cooling of the Barents Sea continues, the resulting BSW feeding the deep waters of the Arctic Ocean and the Norwegian Sea, and subsequently the Atlantic Meridional Overturning Circulation, will by far be the least dense throughout the instrumental period."
>
> *Øystein Skagseth, IMR*

Reference:

Skagseth Ø, **Eldevik T**, **Årthun M**, Asbjørnsen H, **Lien VS**, **Smedsrud LH** (2020) Reduced efficiency of the Barents Sea cooling machine. *Nature Climate Change* 10: 661-666. doi.org/10.1038/s41558-020-0772-6


Photo: Christian Morel / christianmorel.net

Teleconnections affecting the Barents Sea climate

Ever heard of teleconnections? The image of a cell phone may pop up in your mind, but for three Nansen Legacy researchers this is all about how currents of air - far up in the atmosphere - connect the Barents Sea, its climate and sea ice conditions to regions on the other side of the planet. These are stories from our truly entangled and interconnected world.

Arctic sea ice and the weather in northern Europe

In atmospheric science, teleconnections are linked, climate anomalies that occur in widely separated regions on the globe. One well-known example is the North Atlantic Oscillation (NAO), a fluctuating weather phenomenon controlling the strength and direction of westerly winds across the North Atlantic. It has been postulated that reduced sea ice concentrations in the Barents- and Kara Sea in autumn may trigger changes in the stratosphere that force the NAO into a negative phase. Camille Li (UiB) and colleagues were able to find evidence for this proposed causal linkage, meaning that reduced Barents-Kara sea ice in autumn can lead to decreased storminess, below-average precipitation, and lower-than-average temperatures in northern Europe – all weather phenomena of a negative NAO. However, the linkage is highly intermittent: it has been particularly apparent in recent decades, but may not be a systematic feature of the climate system.

Spring Siberian snow and the Atlantic jet stream

Another teleconnection, described in a publication by Nansen Legacy researcher Fei Li (UiB) and co-authors, is the mechanism by which anomalously little snow in Siberia in spring result in significant tropospheric warming that ultimately leads to a weakening of the Atlantic jet stream - a fast flowing meandering air current over the northern hemisphere - and influence sea surface temperatures over the North Atlantic.

Hot cyclones traveling in from the south

The Atlantic jet stream also has an impact on how many cyclones reaches the Barents Sea from the North Atlantic. In a recent study, Erica Madonna (UiB) and Camille Li (UiB), with others, were able to show that more cyclones reach the Barents Sea when the jet stream is angled towards the Barents Sea. On the other hand, there are fewer cyclones entering when a quasi-stationary high-pressure system over the Barents Sea blocks the cyclones. Cyclones transport warm and moist air from the mid-latitudes. Consequently, they can have a strong impact on the Arctic sea ice through warming and ice melt, sea ice drift and break-up. Both the birthplace and the path cyclones take to reach the Barents Sea have a say in their impact. The study shows that winter cyclones originating in the North Atlantic south of 60°N produce the strongest warming in the Arctic. The location of the sea ice edge has also been proposed by previous studies to affect the path of cyclones, because it creates a strong surface temperature gradient that the cyclones may use as fuel to grow. The recent retreat of sea ice in the Barents Sea could thus be steering the cyclones further north and not east into the Barents Sea, resulting in a poleward shift of the storm tracks. However, the study could not find evidence to support this effect of the sea ice on cyclone paths. ■

> "Thus, we conclude that the atmospheric circulation rather than the sea ice location controls the path of cyclones at high latitudes."
>
> *Erica Madonna, UiB*

References::

Madonna E, Hes G, **Li C**, Michel C, Siew PYF (2020) Control of Barents Sea wintertime cyclone variability by large-scale atmospheric flow. ***Geophysical Research Letters*** 47: e2020GL090322. doi.org/10.1029/2020GL090322

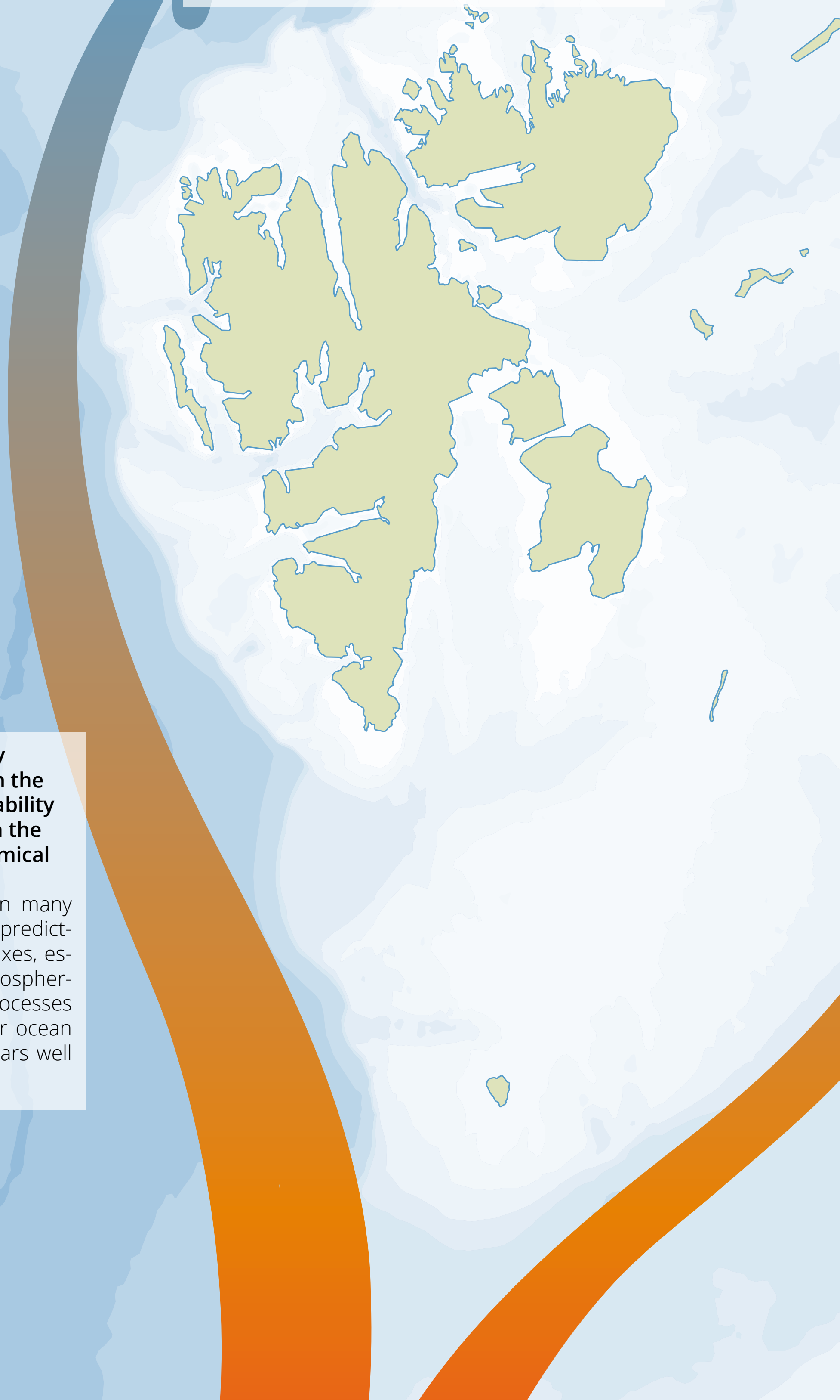
Shen H, **Li F**, He S, Orsolini YJ, Li J (2020) Impact of late spring Siberian snow on summer rainfall in South-Central China. ***Climate Dynamics*** 54: 3803-3818. doi.org/10.1007/s00382-020-05206-5

Siew PYF, **Li C**, Sobolowski SP, King MP (2020) Intermittency of Arctic–mid-latitude teleconnections: stratospheric pathway between autumn sea ice and the winter North Atlantic Oscillation. ***Weather Climate Dynamics*** 1: 261-275. doi.org/10.5194/wcd-1-261-2020

Mapping Nansen Legacy knowledge

Whalers Bay north of Svalbard will become increasingly ice-free in the future, as the heat transport by Atlantic Water (AW) and the storm frequency have increased in this area over several decades[13].

Storms transport the heat from the AW to the sea ice, leading to rapid melting. Storms are no longer a necessary condition for the rapid melting when AW is close to the surface and its temperature is ~5° C. An analysis of new and historical hydrographic data identifies previously unknown circulation patterns in the region north of Svalbard, which may have implications for the transport and variability of the AW into the Arctic Ocean[14].



The predictability of primary production and CO_2 fluxes in the ocean relates to the predictability of the mixed layer rather than the temperature and the initial biogeochemical state.

The mixed layer is less predictable than many other physical drivers. This hampers the predictability of primary production and CO_2 fluxes, especially during summer when chaotic atmospheric processes affect biogeochemical processes in the shallow upper mixed layer. Winter ocean carbon uptake, on the other hand, appears well predictable.

Turbulent mixing at hydrographic fronts and at the continental slope increases the heat and nutrient transport in the Arctic Ocean[11-12].

While turbulence along the continental slope is typically driven by internal dynamics forced by tidal currents[11], processes such as convection and wind-ocean front interactions fuel instabilities and energy transfer from atmosphere and large-scale currents to turbulence[12].

A new method provides operators of autonomous underwater vehicles (AUVs) with an overview of the environmental impact of the AUV operation[15].

It can work as a guide on how to choose the mission patch before the operation, and it also provides the vehicle and operator with a dynamic risk indicator, which can support the AUV's decision making.

Different physical processes lead to the «Atlantification» of the Eurasian part of the Arctic Ocean[2-4].

Inflow of increasingly warmer Atlantic Water is the main cause in the ice-free regions of the Barents Sea[2]. In the marginal ice zone and the ice-covered northern Barents Sea, not only the inflow of warmer water, but also changes in the heat exchange between the sea and the atmosphere lead to increasing water temperatures and sea ice loss. In recent decades, anomalous southerly winds have reduced the heat loss from the ocean to the atmosphere. [3]. Consequently, water masses flowing from the Barents Sea into the deeper central Arctic Ocean have become warmer. The poleward penetration of Atlantic Water has also led to increased upper-ocean salinity, and consequently reduced stratification in the Eurasian basin of the central Arctic Ocean[4].

Climatic changes affect the Barents Sea food web through an interplay of different factors[5-10].

The extension of warm Atlantic Water determines the northwards dispersal of Atlantic fish species in the Barents Sea[5]. Warmer conditions also lead to an earlier onset and development of a stronger phytoplankton bloom in the northern Barents Sea in spring[6]. However, bloom onset cannot be pre-drawn to earlier than mid-May despite earlier ice retreat. Arctic microbial communities are only indirectly affected by changes in temperature, as they are mainly driven by the abundance of the seasonally migrating large arctic copepods[7]. Retreating sea ice has positive effects on the growth of polar cod in the Barents Sea[8]. However, successful recruitment of young polar cod appears to require high ice concentration and low water temperatures well into summer[9]. Planktivorous fish more efficiently prey upon zooplankton over shallow banks[10].

References

[1]Fransner et al. 2020, [2]Asbjørnsen et al. 2020, [3]Skagseth et al. 2020, [4]Polyakov et al. 2020, [5]Eriksen et al. 2020, [6]Dong et al. 2020, [7]Thingstad 2020, [8]Dupont et al. 2020, [9]Gjøsæter et al. 2020, [10]Aarflot et a. 2020, [11]Fer et al. 2020, [12]Koenig et al. 2020, [13]Duarte et al. 2020, [14]Kolås et al. 2020, [15]Yang et al. 2020

One fourth of plan A - The mooring service and physical process cruise

Originally, four major field campaigns to the northern Barents Sea had been planned for 2020. Three cruises had to be postponed by one year due to repairs on the research vessel and COVID-19 related restrictions. Finally, on Oct 6, sixteen Nansen Legacy scientists and technicians were able to head out to the Barents Sea with RV *G. O. Sars*. Their aim: To investigate the Polar Front.

Photo: Christine Gawinski

Polar Front
The Barents Sea Polar Front is one of the sites the project has selected for investigating processes taking place at the boundary between warmer water masses of Atlantic origin and colder water masses of Arctic origin. At the front, increased turbulent mixing often increases the nutrient supply from depths to the surface layers, nourishing the marine food web. Fronts are therefore typically associated with enhanced primary production, high concentrations of zooplankton and fish larvae, and biogeochemical cycling. Consequently, high-quality observations in frontal zones are important for understanding the associated physical-biological interactions and their impact on the marine ecosystem. The Nansen Legacy has so far dedicated four of its cruises to the study of physical processes at fronts, both in the Barents Sea and north of Svalbard.

Expanding observational capabilities
In October 2020, the Nansen Legacy scientists on board RV *G. O. Sars* collected measurements of ocean stratification, microstructure, and currents from the vessel as well as by deploying robotic sampling platforms, such as gliders and autonomous underwater vehicles. Gliders are remotely piloted vehicles that can patrol the ocean for months, measuring water properties at high spatial and temporal resolution. Gliders therefore not only expand the observational capabilities beyond the cruise time, but also provide high-resolution information. The latter is especially important at ocean fronts, where sharp changes in water masses occur. Since 2018, the Nansen Legacy has collected oceanographic data with the help of Seagliders and Slocum gliders in frontal areas north of Svalbard and the Barents Sea, operated by the Norwegian facility for ocean gliders (NorGliders) at the University of Bergen. During more than 300 days, these gliders have collected about 7800 profiles of water properties, as well as 500 microstructure profiles. A study led by Eivind Kolås (UiB) exploited the new dataset to identify previously unknown circulation patterns in the region north of Svalbard, which may have implications for the transport and variability of the Atlantic water into the Arctic Ocean.

Exploring ocean turbulence
Turbulent mixing in the water column affects fluxes of heat, dissolved gases and nutrients in the sea. Cruises and gliders combined, the Nansen Legacy has collected 1200 turbulence profiles, equivalent to more than 300 km stretch of turbulence records. In two recent studies from north of Svalbard, Ilker Fer (UiB) and Zoe Koenig (UiB) found that turbulent mixing at the front and at the continental slope increases the heat and nutrient transport in the Arctic Ocean. Observations from the shelf north of Svalbard emphasize the role of tidal dynamics in generating turbulent mixing. ■

> "The circulation patterns, the frontal dynamics and drivers of turbulent mixing in the northern Barents Sea are largely unknown. The new dataset collected in the Nansen Legacy will help close this knowledge gap."
>
> *Ilker Fer, UiB*

References:

Fer I, **Koenig Z**, Kozlov IE, Ostrowski M, Rippeth TP, Padman L, Bosse A, **Kolås E** (2020) Tidally forced lee waves drive turbulent mixing along the Arctic Ocean margins. *Geophysical Research Letters* 47: e2020GL088083. doi.org/10.1029/2020GL088083

Koenig Z, **Fer I**, **Kolås E**, Fossum TO, **Norgren P**, **Ludvigsen M** (2020) Observations of turbulence at a near-surface temperature front in the Arctic Ocean. *Journal of Geophysical Research: Oceans* 125: e2019JC015526. doi.org/10.1029/2019JC015526

Kolås EH, **Koenig Z**, **Fer I**, **Nilsen F**, **Marnela M** (2020) Structure and transport of Atlantic water north of Svalbard from observations in summer and fall 2018. *Journal of Geophysical Research: Oceans* 125: e2020JC016174. doi.org/10.1029/2020JC016174

Nansen Legacy glider missions

North of Svalbard
Seaglider mission 1
17 Sep – 11 Nov 2018
754 profiles

Barents Sea
Seaglider mission 2
7-19 Aug 2019
308 profiles

Seaglider mission 3
15 Nov 2019 - 22 Feb 2020
2568 profiles

Seaglider mission 4
22 Oct 2020 - 5 Feb 2021
2500 profiles

Slocum glider mission 1
14-21 Sep 2018
194 profiles with turbulence probes

Slocum glider mission 2
08-24 Oct 2020
801 profiles (308 with turbulence probes)

Slocum glider mission 3
10-20 Oct 2020
678 profiles

Plan B, C and D – Alternative field campaigns and work in 2020

The work of many of the project's early career scientists is heavily dependent on samples from the field. Therefore, the postponement of planned Nansen Legacy research cruises from 2020 to 2021 severely threatened the progress of PhD theses and postdoctoral publications. Yet, creativity, collaboration and old data led to many good alternative plans, as seen from these three examples.

Taken onboard by friends
Postdoctoral fellow Tristan Petit (UiB/ NPI) had planned to gather most of the data on inherent optical properties of seawater in the Barents Sea during the Nansen Legacy cruises in spring 2020. None of these cruises could take place. Luckily, COVID-19 related restrictions on fieldwork were relaxed by summer 2020, and Tristan was invited onboard by the NERSC-led UAK2020 cruise to Storfjorden, Svalbard in June, and an NPI-led FS2020 cruise to the Fram Strait in September.

Old and new data
PhD student Christine Gawinski (UiT) had also planned to join two Nansen Legacy cruises in 2020, which were supposed to give her precious information on the seasonal development of small, understudied copepod species in the Barents Sea. Christine had already started the seasonal study with two cruises in 2019, and the postponement of cruises in 2020 severely affected her research. A new idea for a publication was found in old, unpublished data on small copepods at the Polar front in the Barents Sea, which were complemented with new data gathered during the Nansen Legacy Mooring service and physical process cruise in October 2020, which Christine spontaneously joined.

Fieldwork at home
Nansen Legacy PhD students Maria G. Digernes (NTNU), Marti Arumi (UiT), Stephen Kohler (NTNU) and Yasemin Bodur (UiT) were in the same situation as Tristan and Christine – they were all dependent on samples from Nansen Legacy cruises in 2020. Their response to the cruise postponement was to organize their own fieldwork in the seasonally ice-covered Ramfjord near Tromsø. They had found that, although working in different disciplines, they shared an interest in how dissolved organic matter is turned into particles and vice versa, and how the particles attract trace metals. The four designed a complex experimental set-up to investigate this process with water from Ramfjord. Three such experiments were conducted between September and December 2020, and the work will continue in 2021 beside fieldwork in the Barents Sea. ■

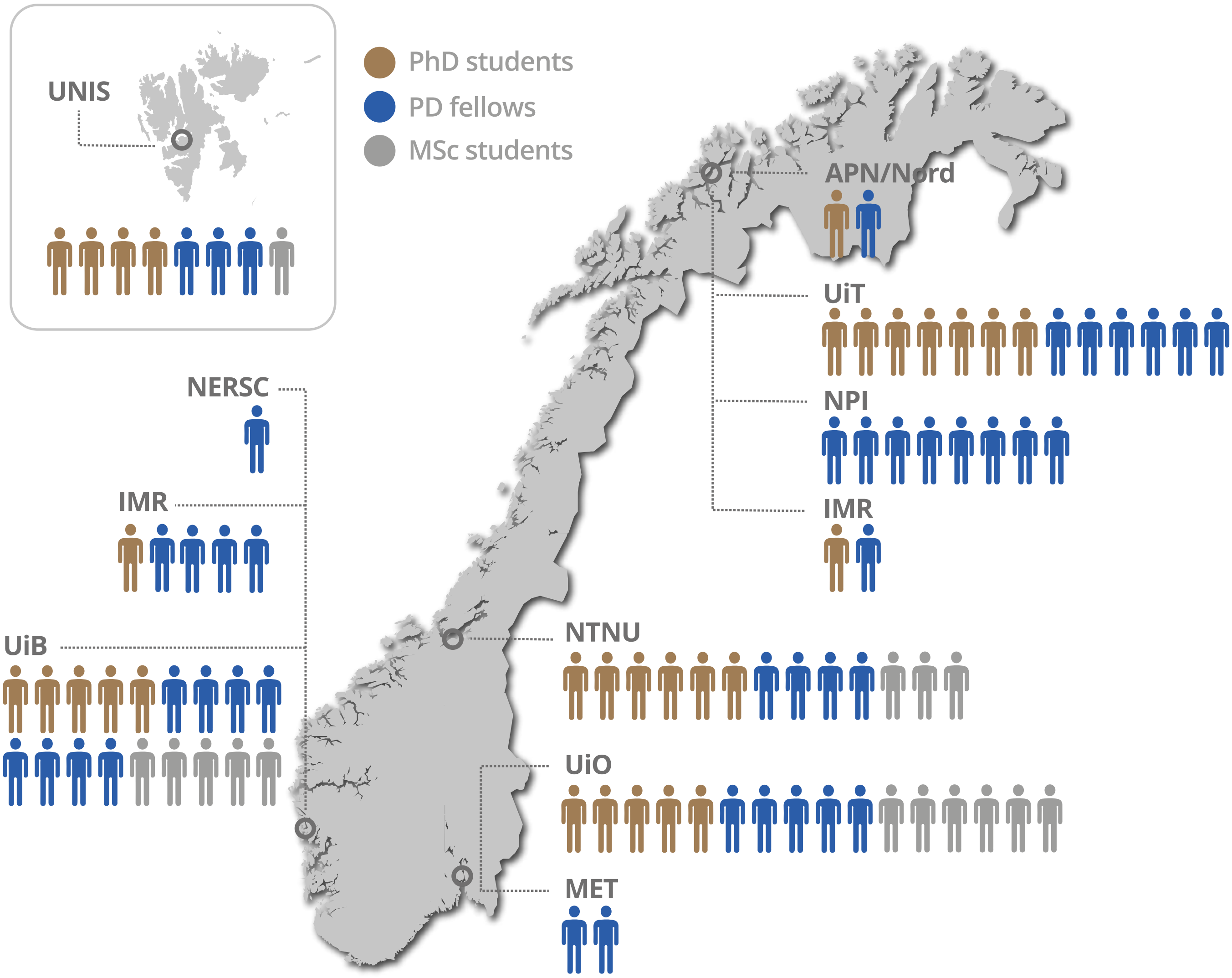
"The work in Ramfjord has closed a huge gap year in my PhD project, and I am not sure if I could finish on time without this opportunity."

Yasemin Bodur, UiT

The COVID-19 lockdown in spring 2020 threatened the maintenance of the 192 microalgal cultures, which Nansen Legacy scientists from UiO have isolated from the Barents Sea and the Arctic Ocean. Here, PhD student Karoline Saubrekka (UiO) inspects some of the cultures. The algae cultures will become publicly available through the Norwegian Culture Collection of Algae (NORCCA) during spring 2021.
Photo: Luka Supraha

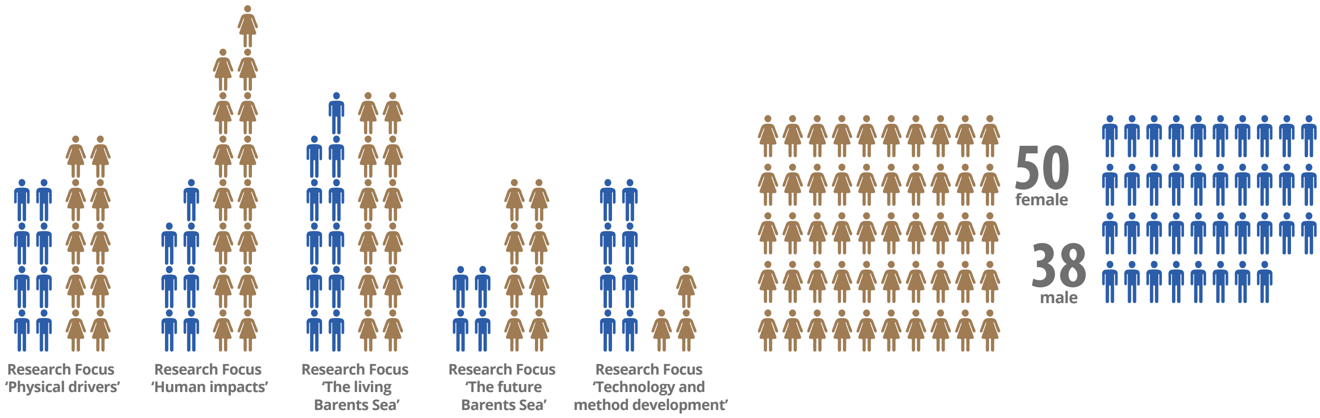
Early career scientists

A new generation of polar researchers is needed to face and cope with the challenges of a rapidly changing Arctic. The Nansen Legacy educates a growing number of early career scientists in a cross-disciplinary and multi-institutional manner.



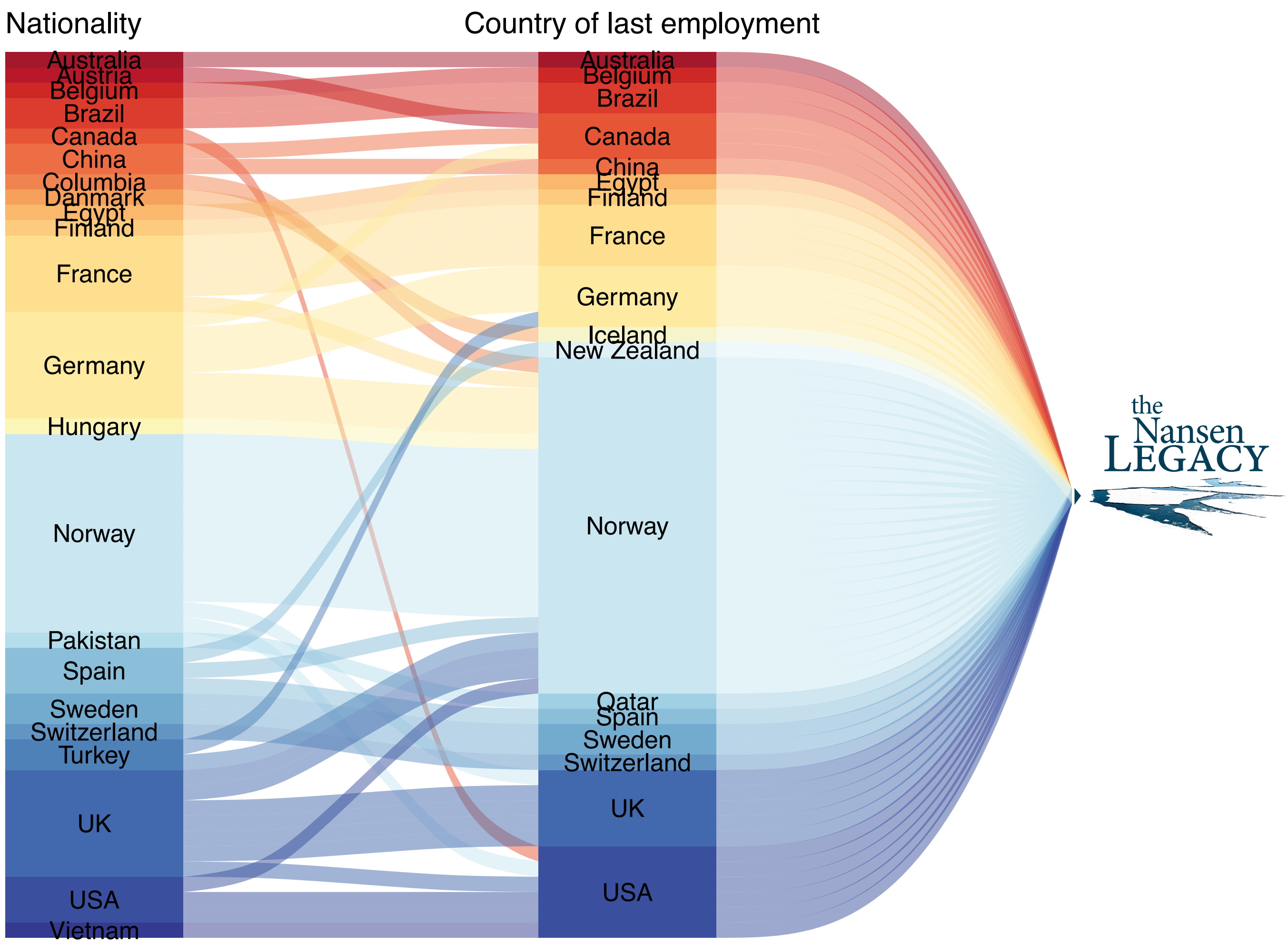
The Nansen Legacy early career scientists are diverse with respect to career level and nationalities, as well as institutional and disciplinary homes. They represent different career stages, with 28 PhD students and 45 postdoctoral scientists. While most of this group is funded by the Nansen Legacy, a growing group of (currently) 15 young scientists are affiliated with the project, expanding the project's expertise and research capacity. They work with samples or data obtained through the Nansen Legacy to complement the planned research at Nansen Legacy partner- or collaborating institutions. Several master's students are also being educated as part of the project.

The early career scientists are spread all over Norway and the ten Nansen Legacy institutions. The universities are home to a large fraction of the young scientists, as only few MSc and PhD students are affiliated to the institute sector.



Among the early career scientists of the project, women contribute entire 57%, outnumbering men in most research foci. One exception is the work package on technology and method development. However, while female senior scientists constitute a scarce 11% of all seniors in that work package, 30% of the early career scientists in the same work package are women, reflecting the general trend of increased recruitment of female scientists in all fields of science.

The international component among the early career scientists is strong, with 22 different nationalities recruited from 18 different countries. The project attracts promising young scientists from abroad, but also highly motivated Norwegian candidates. Norwegian citizens are generally recruited from Norwegian institutions, implying that Norwegians still tend to build their careers in Norway. However, half of the recruits from Norwegian institutions are not Norwegian citizens. The large influx of competitive international candidates directly to the Nansen Legacy project, suggests that a concerted and highly visible effort like this one is attractive in the international research landscape. ■



The Nansen Legacy as a multi-institutional and cross-disciplinary home

The Nansen Legacy aims at providing its early career scientists with a multi-institutional and cross-disciplinary network. Different structures have been implemented to reach this goal.

One postdoc, two employers

The project has ventured a new way of employment by employing four of its postdoctoral fellows at two different institutions. The rationale behind is to use these double-employments to overcome institutional boarders, strengthen collaboration and offering the candidates prolonged employment times. Both UiB and NPI, for example, employ postdoctoral fellow Zoe Koenig, for a total period of four years. After her first two years in Bergen, Zoe moved to Tromsø in late 2020.

"It's a good deal for me. I get to know two different institutes without losing time in applying for a new 2-year postdoc position."

Zoe Koenig, NPI/ UiB

One PhD, several supervisors

Over half of the Nansen Legacy PhD students have supervisors at two or more Nansen Legacy institutions in order to foster cross-institutional integration as well as efficient utilization of research infrastructure at different institutions. The project has dedicated funding for enabling travel and mobility between institutions. PhD student Snorre Flo, for example, has his supervisors both at UNIS and UiT. Although his main workplace is on Svalbard, he regularly spent time in Tromsø where he uses the laboratory facilities for the analysis of his samples.

"Having supervisors from different environments helps ensure that the research is of interest to a broader scientific community."

Snorre Flo, UNIS

Informal meeting places

The Nansen Legacy believes that cross-disciplinarily is best facilitated by providing a meeting and mingling place for its early career scientists. Therefore, the project organizes annually a two-day long meeting, the Recruit Forum, for its young scientists. Here, the early career scientists get to meet in an informal setting, talk about their science and discuss topics of interest. It was during one of these meetings that four of the PhD students from Trondheim and Tromsø discovered a joint interest leading to the design of an innovative experiment series based on fieldwork in Ramfjord.

"Being part of the Nansen Legacy gives me the ability to discuss and develop ideas for projects with researchers across marine disciplines. After all, the ocean is a diverse ecosystem and to discuss one topic one needs to tap into many of the interconnected areas."

Maria G. Digernes, NTNU

Workshops serving the early career needs

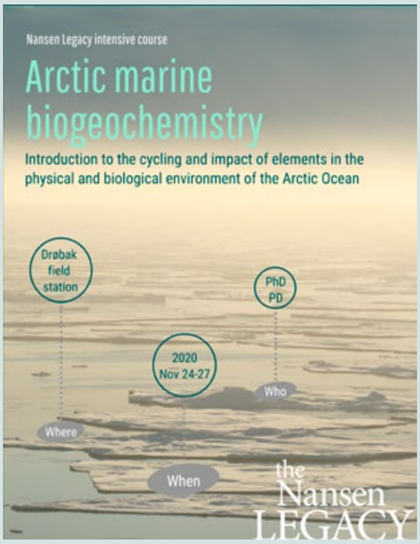
The project has funding opportunities for project internal workshops, that also can be applied for by the early career scientists. Several workshops have so far been initiated and organized by early career scientists. Examples include a meeting for developing paleo age-models on Nansen Legacy cores (November 2020), and a three-day workshop on reproducible data wrangling, visualization and collaboration with R and GitHub (January 2021).

"I feel I have gained a large and approachable network from the Nansen Legacy and have had several extracurricular opportunities from courses and activities organized by the project."

Robynne Nowicki, UNIS

Nansen Legacy intensive courses

Educating a new generation of Polar scientists in a cross-disciplinary way is a core goal of the Nansen Legacy. For this endeavor, the project arranges intensive courses in which topics of interest to all Nansen Legacy early career scientists. In 2020, the following courses were held.

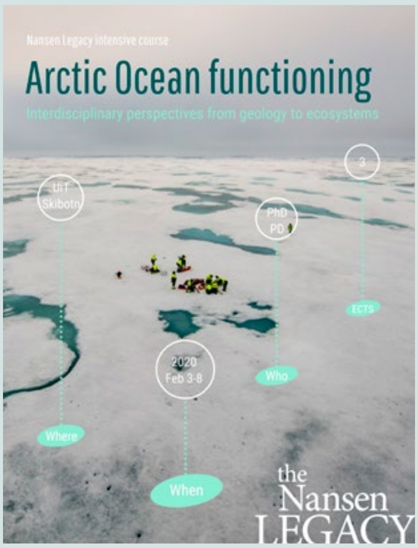


Arctic Ocean functioning – Interdisciplinary perspectives from geology to ecosystems

The first Nansen Legacy interdisciplinary intensive course for PhD students and postdoctoral fellows was held at UiT's field station in Skibotn. Participants included 19 lecturers from six Nansen Legacy institutions, and 18 students from nine Nansen Legacy institutions. The course was arranged into four overarching themes: advection, stratification, sea ice, and ecosystem – one theme per day. Each theme was presented from different disciplinary angles from several lecturers. Throughout the course, students also worked in groups, building a conceptual model in which their own research was coupled with the research of the other members of the group. The course led to valuable cross-disciplinary discussions, generating new research ideas between Nansen Legacy scientists, and hence serving also as a seeding bank for new interdisciplinary collaboration.

Multi-factor experiments in marine science – Data and analysis

In October, several members of the SCOR Working Group on Changing Ocean Biological Systems held a one-day course for Nansen Legacy and ARCTOS members, centered around their Best Practices Guide for multi-factor experiments. Constraints on traveling led to an unusual format whereby multiple in-person nodes around Norway and Denmark were linked via Zoom where break-out working groups were enabled, and lectures and practical work facilitated. In all, 23 PhD students, postdoctoral fellows, technicians, and seniors scientists participated, along with course leaders John Havenhand (Tjärnö Marine Biological Station, Gothenburg University, Sweden), Christina McGraw (University of Otago, New Zealand), and Paul Renaud (Akvaplan-niva/UNIS/Nansen Legacy, Norway).



Arctic marine biogeochemistry – Introduction to the cycling and impact of elements in the physical and biological environment of the Arctic Ocean

In this four-day course, 13 PhD students and postdoctoral fellows received an introduction to the role of the Arctic Ocean in the global biogeochemical cycle, ocean acidification, the use of biogeochemical tracers for oceanographic studies, land-ocean coupling, and the intricate interplay between Arctic organisms and their physio-chemical environment. The course was developed and lead by Nansen Legacy seniors from four of the partner institutions. Additionally, Emil Jeansson (NORCE) and Howard Browman (IMR) contributed with their expertise to the success of the course. Due to covid-19, the course was held virtually. ■

Start-up

One and half year ago, four young scholars from the Norwegian University of Science and Technology started Skarv Technologies AS, a company delivering software- and hardware solutions for marine autonomous robotic systems. Among the four founders are Nansen Legacy postdoctoral fellow Petter Norgren and Nansen Legacy PhD student Tore Mo-Bjørkelund.

– Petter, you just finished your postdoctoral period in the Nansen Legacy. What were you working on in the project?

Petter: In the Nansen Legacy project, I was working on under-ice navigation for autonomous underwater vehicles. Underwater positioning is a very challenging problem, especially in the Arctic and with the presence of sea-ice. Without good navigation it is very hard to perform autonomous operations. Through the project, I designed buoys with acoustic communication and positioning capabilities that would be used during Arctic research campaigns to aid the underwater robot in its task of collecting valuable data.

– How did you like working in a large cross-disciplinary research project such as the Nansen Legacy?

Petter: The use of underwater robots is a tool for a user – typically to collect data. I enjoyed working in a large cross-disciplinary research project since it gave me the opportunity to get feedback from the end-users of the data that we collect.

– Tore, also you are a marine technologist, halfway through your PhD within the Nansen Legacy. What are you working on right now?

Tore: I am working on adaptive behavior for sensor carrying AUVs, where the behavior is constrained by the data requirements of the end-user and the vehicle itself. I hope to expand the adaptive strategies to include more vehicles, cooperating to gather more synoptic data. I also have a side project gathering data under the ice using an experimental robot.

– As a PhD student in a cross-disciplinary project, do you feel that it can be difficult to balance the width of the scientific framework of the Nansen Legacy, and the scientific depth and specialization that is needed for writing a PhD?

Tore: One of the main challenges as a technology-PhD is the gap between the established methods in science and the experimental methods we are developing. Bridging this gap and giving useful data to the scientists with the tools we use for technology research is not always straight forward.

– One and half year ago, you two started a company together with two former colleagues from NTNU. Petter, how did the idea for starting Skarv Technologies AS come up?

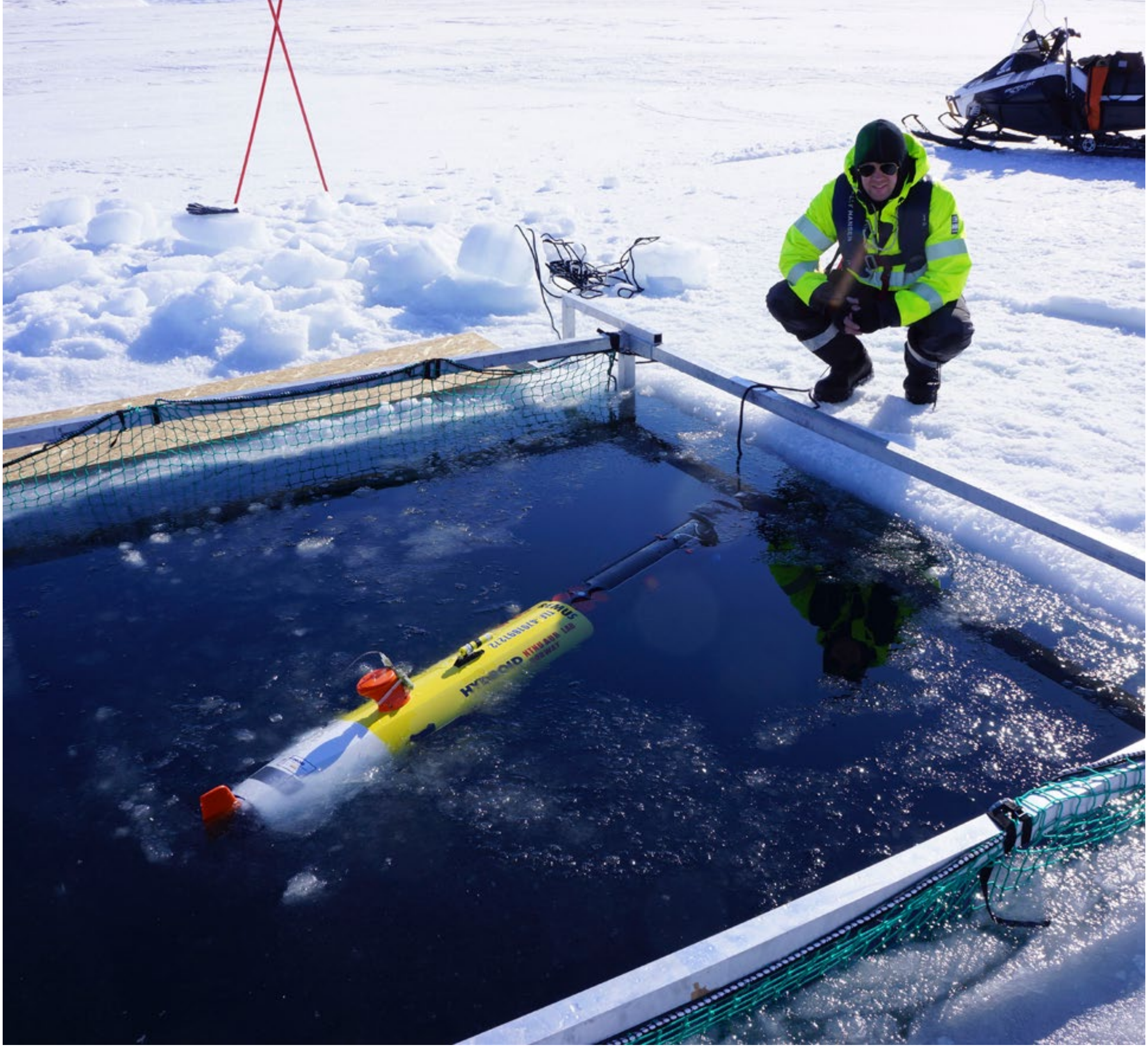
Nansen Legacy early career scientists Petter Norgren (left) and Tore Mo-Bjørkelund (right) from the Norwegian University of Science and Technology started Skarv Technologies AS, a company delivering software- and hardware solutions for marine autonomous robotic systems.

Petter: The team behind Skarv Technologies have been working closely on different research projects for several years, with countless days in the field. Through the work we have done at the Applied Underwater Robotics laboratory, we have gotten a unique experience working with real underwater robotic applications, and we agreed that with our collective knowledge and experience we would make a good team also in a commercial setting. And that is how the company got started.

– What kind of services does Skarv Technologies AS provide?

Petter: Skarv Technologies started as a consultancy company, and we provide consultancy services within data analysis and visualization, as well as autonomous platform development and survey support. In addition to this, Skarv Technologies develops in-house software for increasing underwater robot autonomy and situational awareness, which will aid underwater robots to perform more intelligent decisions based on the collected data.

– Both of you have used autonomous marine robots under harsh arctic conditions. What is the biggest challenge for the application of this technology in the Arctic at the moment?



Nansen Legacy postdoctoral fellow Petter Norgren (NTNU) on the sea ice in Svalbard for the testing of the autonomous underwater robot 'Remus' under arctic conditions. Photo: NTNU AURlab

Tore: I see two main challenges for autonomous marine robots in the Arctic: one is the ice cover, making surfacing to get the GPS position harder, the second challenge is the availability of cheap and robust robotic platforms that can be deployed and recovered from icebreakers without using "silk gloves". The first challenge can be solved by tightly integrating the robot and the on-board positioning systems such as the HiPAP on RV *Kronprins Haakon*. The second challenge must be solved by robustification and further research into design of underwater vehicles for under-ice operations.

– Do you think that autonomous robotic systems will play an essential role in arctic marine research in the future?

Tore: Once autonomous systems are accepted as a part of the vessel, such as the CTD, we can expand our understanding of what a ship is. The ship ceases to be a sensor carrying platform and becomes a mothership. A high-end autonomous underwater system can cover the entire water column, and have long endurance, enhancing the sensing capabilities of the ship, while being vastly more inexpensive and resource demanding. The same is true for surface and arial systems, and if we can integrate these robots into our working method, we can go from having point-measurements to having synoptic overviews of ocean processes.

– Petter, do you think that your time in the Nansen Legacy has taught you something that will be of help for your company?

Petter: I think my time in the Nansen Legacy has taught me the value of working interdisciplinary, and to focus on the needs of the end-users before developing new technology. There is no use in developing a fancy technology or feature if no one is going to use it.

– Do you have some recommendations for other young academics who wish to start their own company?

Tore: You do not need a fully formed idea, it will change anyways. What you need is perseverance and the willingness to try and fail.
Petter: I would say that the most important part of starting your own company is to have a good team at your back – you cannot do everything yourself and you need to rely on your colleagues to succeed. ■

Master theses 2020

The Nansen Legacy educates young researchers at master, PhD and postdoctoral levels. In 2020, the first three Nansen Legacy master students graduated.

Aleksander Dürr Libæk was a master student at UiB, supervised by Ilker Fer and Zoe Koenig. In his master thesis Libæk addressed the tidal forcing and internal tide generation over continental shelves and plateaus in the vicinity of Svalbard using a high-resolution (2.5 km) Regional Ocean Model System (ROMS) setup. The motivation for the study was that tidal currents running over varying bottom topography may increase the mixing of the water column above. This may also increase the distribution of heat energy coming along with the Atlantic water to Svalbard, and thus influence the processes involved in sea ice melt. Libæk's study contributes to an improved description of the diurnal and semidiurnal tidal currents around Svalbard and suggests that tidal currents are an important contribution to vertical mixing and the evolution of water mass properties in the region.

Reference: Dürr Libæk A (2020) Tidal forcing and internal tide energetics around Svalbard: a numerical study. Master thesis, University of Bergen.

Anjali Gopakumar was an exchange student from Gehnt University, Belgium, who carried out her master study at UiO, supervised by Katrine Borgå and Julia Giebichenstein. Gopakumar quantified total mercury (Hg) concentrations and dietary descriptors in three Arctic and sub-Arctic fish species, to study their interspecific and spatial bioaccumulation patterns in the Barents Sea food web. This study was the first to quantify total Hg concentrations during the polar night, and showed that Hg concentrations varied greatly among individual fishes, but were in general well below the EU-accepted threshold for human consumption of 0.5 µg/g (wet weight). The results further revealed a marked influence of trophic position on total Hg accumulation, with highest Hg levels found in the benthic-pelagic living Atlantic cod.

Reference: Gopakumar A (2020) Mercury accumulation in fishes from north-east and north-west Barents Sea during the polar night. Master thesis, University of Oslo.

Leah Strople was a master student at UiB, supervised by Ireen Vieweg (UiT), Anders Goksøyr, Fekadu Yadetie and Odd André Karlsen (UiB). Strople performed an experimental study which a was carried out at Kårvika field station in Tromsø. Here, wild-caught polar cod were exposed to the water-accommodated fraction of crude oil or control conditions over their spawning period, at either a high or low food ration. Polar cod spawn during winter, and if an oil spill were to occur during the polar night, exposure could lead to disruption in natural reproductive development and spawning, which would be reflected in the gene expression for various endpoints related to gonad development and sexual hormones. Results showed that exposed females spawned earlier than non-exposed females, but that food ration did not have any effects. The former result was contrary to what has been shown in previous experiments, but this difference may be explained by variations in the timing of exposure during the reproductive cycle.

Reference: Strolpe L (2020) Spawning during an oil spill – How exposure to the water-accommodated fraction of crude oil may disrupt polar cod (*Boreogadus saida*) reproduction. Master thesis, University of Bergen.

> To the right: Sine Sara Astad is a master student at UNIS investigating the species composition and population dynamics of small-sized and understudied copepods. In October 2020, Sine joined the Mooring and physical process cruise to the Barents Sea to collect samples for her work.
Photo: Ragnheid Skogseth


100 Gloves

< Nansen Legacy on TV. In January, the Norwegian TV channel NRK launched the documentary series ‘SnowHow – The Nordic Winter’, which is a Nordic production about several aspects of winter. The production team had joined a Nansen Legacy research cruise in August 2018, capturing pictures of Nansen Legacy researchers working out on the sea ice, and featuring especially Nansen Legacy researcher Agneta Fransson (NPI) and her work on the impact of ocean acidification on the arctic marine ecosystem. The series was broadcasted at prime time in Norway, Sweden, Finland and Denmark. The series is sold to Poland, Estonia, Czech Republic, six Balkan countries, and is now also launched in Asia.
Picture: NRK

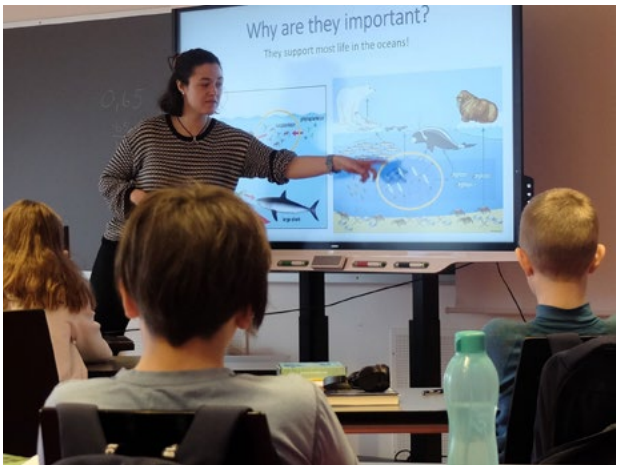
Outreach

Nansen Legacy scientists used the project's third year to communicate their research and knowledge to a broad audience, ranging from school kids to the government's parliament group. Examples of the project's dissemination activities in 2020 are given below.

For and with kids

"Imagine you are a fish, a polar cod, living in the ocean about halfway between Norway and the North Pole" - is how the Nansen Legacy's first scientific publication for kids starts. It was authored by Nansen Legacy scientist Leif Christian Stige (UiO) in the journal Frontiers for Young Minds and explains in simple words the complex interplay between seawater temperature and species composition for the structure and function of the Barents Sea food web. The paper received an excellent review by 9-year-old Vardhan.

Throughout 2020, Nansen Legacy scientists from UNIS, UiO and UiT also met with children and teenagers to talk about science and the Arctic natural environment, either virtually through platforms like "Skype a scientist" and "Meet a Marine Biologist Monday", or in person at schools in Norway, USA, UK and Germany. In total, approximately 190 pupils were involved. Additionally, the Nansen Legacy collaborated with the Arctic Frontiers conference and the Science Centre of Northern Norway in the project "Science for kids" during which eighty 5-year-olds received a hands-on introduction on how to conduct own research.



Nansen Legacy PhD student Robynne Nowicki (UNIS) introduces the pupils of the 6th grade at Longyearbyen school to the importance of copepods in the arctic food web.
Photo: Eva Therese Jenssen/ UNIS

For and with scientists

The Ocean Sciences Meeting is the flagship conference for the ocean sciences and the larger ocean-connected community. In 2020, the conference was held in San Diego, USA. Here, the Nansen Legacy organized under the lead of Filippa Fransner (UiB) an oral session on Near-Time Predictions of the Ocean: Physics, Biogeochemistry and Ecosystems. This was done in collaborations with

With 'Science for kids' the Science Centre of Northern Norway and the Arctic Frontiers conference invite kindergartens in Tromsø to create their own science project. In 2020, the Nansen Legacy was onboard with a research project on "How much salt is in the sea?", where about 80 five-year olds measured the salt content of seawater by merely using their tongue.
Photo: Nordnorsk Vitensenter

scientists from Max Planck Institute for Meteorology, Germany and from University of Colorado, USA. The session attracted many leading scientists within the field of inter-annual-to-decadal predictions and resulted in interesting cross-disciplinary discussions.

The project also arranged several webinars on specific scientific topics in order to enhance the visibility of ongoing research within the Nansen Legacy and the dialogue between scientists. Topics for such webinars were for example "leads", a physical feature of ice-covered seas that several Nansen Legacy researchers from different fields are working on, including large-scale sea ice modelling (NERSC), sea-air exchange of CO_2 (IMR) and marine primary productivity (NPI).

For and with politicians

Where is the ice edge position in the Barents Sea? This was one of the big political discussions in Norway in spring 2020. The reason: The choice of definition results in a geographic positioning of the ice edge that also determines how far north into the Barents Sea activities like oil exploration will be admitted. Nansen Legacy scientists engaged in the debate. The projects' co-PI Tor Eldevik (UiB), for example, held a research-based presentation on the topic for the government parties' parliamentary group together with a representative from NPI.

Several Nansen Legacy scientists contributed to the second order draft of the IPCC working group 1 report, which was reviewed by governments and experts in spring 2020. ■

Do you think we know whom we share this planet with? **Then you are mistaken.**

The Nansen Legacy runs its own research blog on 'forskning.no' since 2018. In 2019, an English version on 'sciencenorway.no' followed. In 2020, one of the Nansen Legacy blog posts was among the ten most read on both platforms, and made it even across the Atlantic onto the American research news platform 'realclear-science.com'. Here you have the chance to read the blog post once more.

Written by Bodil Blum, UiT

I am privileged. I have worked in some of the most remote places on this planet, and I have seen forms of life that only few know of, some of which have not yet gotten a name. In 2005, for example, my husband and I came across a tiny small jellyfish living in the salty channels inside Arctic sea ice, which had so far been unknown to scientists. Along with an Italian colleague we described this new species, and he surprised us by suggesting naming it after our then newborn daughter. *Sympagohydra tuuli* (first word means jelly poly living with ice) is now one of the ca. 233 000 scientifically described species in the global ocean (excluding bacteria and the like), and of about 1.2 million described on the planet.

It is hard to know how many species there actually are, but some research suggests that there are hundreds of thousands if not millions that are unknown and undescribed as yet. That is an inconceivably large number, and it is natural to wonder what all these life forms do. Although we cannot answer this question for each and every one of all species, we can be certain that they are crucial for the maintenance of the different ecosystems on Earth.

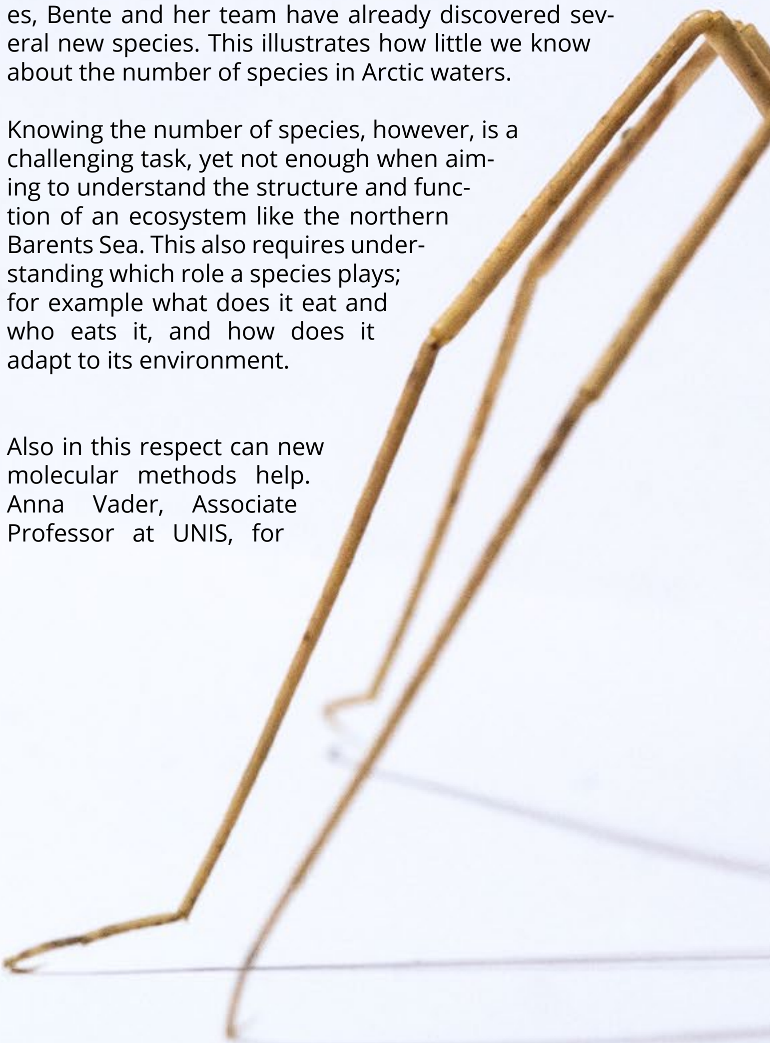
Each year on May 22 the United Nations arranges the 'International Day for Biological Diversity'. On the website for this day, the Convention on Biological Biodiversity states that "despite our technological advances we are completely dependent on healthy and vibrant ecosystems for our health, water, food, medicines, ...".Knowing the marine biodiversity is of high importance given that 70 per cent of our planet is covered by oceans. That is why marine biodiversity is also a core field of investigation within the Nansen Legacy project, which aims at building the knowledge base for the sustainable management of the northern Barents Sea and adjacent Arctic Basin through the 21st century.

In the Nansen Legacy we map biodiversity from viruses to vertebrates, from boreal to Arctic, from sea ice to seafloor, from winter to summer, and from the shelves to the deep basin. Most of the larger invertebrates, fish species and marine mammals and birds are of course known, though their distribution in our study area is not mapped for all of them. Many of the smaller invertebrates and certainly the microbial diversity are not yet documented. In the end, it is all species combined that support the productivity and functioning of the ecosystem of the northern Barents Sea and adjacent Basin.

In the Nansen Legacy, many of us across different institutes contribute to the biodiversity aspect of the project. My colleague Bente Edvardsen, professor at UiO, and her group, for example, is one of the teams combining modern molecular approaches with traditional morphological methods in order to map the poorly mapped diversity of minute algae. After only two cruises, Bente and her team have already discovered several new species. This illustrates how little we know about the number of species in Arctic waters.

Knowing the number of species, however, is a challenging task, yet not enough when aiming to understand the structure and function of an ecosystem like the northern Barents Sea. This also requires understanding which role a species plays; for example what does it eat and who eats it, and how does it adapt to its environment.

Also in this respect can new molecular methods help. Anna Vader, Associate Professor at UNIS, for



example links species to their ecological function, that is what these species do, by decoding their molecular make-up. As with any method, molecular methods cannot tell everything, and we therefore combine these methods with extensive experimental work and many hours over microscopes.

How should we get our children, our parents and anyone else excited about biodiversity of tiny Arctic microalgae or Arctic fishes that no aquarium will ever have? A DNA sequence by itself won't do. We must show what the amazing biodiversity of our home ocean looks like using images and video.

Documenting what species in the icy Arctic Ocean really look like is actually not an easy task, even at a time when every cell phone has a camera. For minute organisms it takes high-powered microscopes. Post-doc Luca Supraha uses a scanning electron microscope for taking images of alga smaller than the width of your hair.

For bigger animals, photography of life material is essential to capture color and vitality. The project is therefore working together with biologist and wildlife photographer Fredrik Broms who currently documents the diversity of animals living at the seafloor of the Barents Sea. His picture collection contains over 150 species so far. While that is just a fraction of all so far known species in that area, it is a fantastic start to bringing the biodiversity of the northern Barents Sea to all who do not have the privilege like me to conduct research in the northern Barents Sea and admire these creatures alive. It is a start to show the beauty and diversity of life forms to my daughters, parents and anyone else who wishes to know with whom we share this planet. ■

The carnivorous sea spider, ***Nymphon stroemi***, is found living on the bottom of the Barents Sea and the Siberian seas. The body of this sea spider is only about 1.5 cm in length, but because of its long legs, individuals can in total measure 15 cm across. The small size of the central body leads to that *Nymphon* carries some of its inner organs in the legs. Among sea spiders, it is the males carrying the eggs. The individual shown here is a male as seen by the black bundles on the specialized egg-bearing appendages in the image.

Photo: Fredrik Broms / northernlightsphotography.no

International collaboration and mobility

Although a Norwegian research project, the Nansen Legacy is tightly connected to the international Arctic marine research arena through collaboration with other research projects, research communities and institutions.

Collaboration on biodiversity in plankton and benthos

Mapping the biodiversity in the seasonally ice-covered northern Barents Sea and adjacent Arctic Basin is an important task in the Nansen Legacy. A collaborative agreement with the Institute of Oceanology, Polish Academy of Sciences (IO PAN) on the microscopic analysis of phytoplankton, zooplankton and benthic invertebrates ensures high quality analysis of the collected data. With their expertise on arctic marine fauna and flora ensure that data collected by different scientists are analyzed using identical criteria and are comparable across Nansen Legacy cruises. This long-lasting collaboration between IO PAN and many Nansen Legacy project partners makes the biodiversity data comparable with both NPI time series and research data from UiT and UNIS from the Svalbard/Barents Sea-region. Workshops on phytoplankton taxonomy have harmonized methods with UiO and NIVA, and analyses of benthic invertebrates are comparable with analyses from the DBO project, hence facilitating Pan-Arctic comparison.

Synergies with MOSAiC

The Arctic Ocean drift experiment with MOSAiC and the Nansen Legacy seasonal study provided an excellent opportunity for synoptic investigations in the deep basin of the Arctic Ocean and on the adjacent shelf. With the COVID-19 pandemic several plans for collaboration were cancelled. This included e.g. atmospheric airborne measurements that were supposed to connect the Nansen Legacy seasonal cruise planned for March 2020 with the MOSAiC drift. Three Nansen Legacy early career scientists still succeeded in bridging activities between the two projects by participating in parts of the 1-year long MOSAiC drift as part of the HAVOC and AROME projects.

Ocean Acidification effects across the Arctic Ocean

Using common analytical approaches facilitates compilation of data across projects and geographic regions. Common analytical approaches are therefore important for the study of biological effects of ocean acidification and climate change. The Japanese JAMSTEC group holds expertise and infrastructure for all fields in marine science. Through the specialized expertise and measurements of morphology and bulk density for micro-sized objects by Micro-Focus X-ray Computed Tomography (μXCT) offered by JAMSTEC, the Nansen Legacy has been given the opportunity to get data on shell density and morphology of pteropods and foraminifera sampled in the Barents Sea. Moreover, collaboration with JAMSTEC provides a comparison between of the Nansen Legacy samples with similar samples from the Pacific Arctic, which have significantly different environmental conditions regarding ocean acidification. This helps in understanding the connection between environmental variables and calcifying zooplankton shell condition in a Pan-Arctic setting. ■

> "Participating in both the Nansen Legacy cruises and the MOSAiC drift, leg 4, the collaborative synergies and benefits were many. Sampling and analytical methods were synchronized and adapted to allow a better cross-comparison of samples taken across the projects. Presenting Nansen Legacy work to MOSAiC colleagues and vice versa, and working closely together with colleagues in both projects, inspired many ideas and plans regarding publications, data sharing and further collaboration in future projects. Personally, my experiences from the Nansen Legacy cruise in August 2019 allowed me to take on more responsibility during the MOSAiC work, which in turn helped me to organize more during the March 2021 Nansen Legacy cruise. Furthermore, I could create a truly unique dataset that will greatly improve our understanding of microbial abundance and processes in the marine Arctic."

Oliver Müller, UiB

Photo: Lars Robert Hole

A handful of suitcases teach us how waves and sea ice interact, and improve weather and sea state models

Waves in ice-covered waters are an amazing scene. It is as if a snow-covered landscape suddenly starts dancing rhythmically. The waves' wildness from the open sea is dampened by the ice. Yet, the waves' energy can break solid sea ice, greatly affecting sea ice drift, formation, and melt. Hence, waves in ice are an important - yet not well-understood - factor in the arctic physical environment.

The need for suitcases in the age of satellites

Satellites have been monitoring arctic sea ice distribution since the 1970s and have provided us with an unprecedented amount of information on a changing environment. Yet, retrieving information on waves in ice-covered waters from satellite measurements is still challenging, and consequently our understanding of this process is limited. Improved understanding and modelling of wave propagation in sea ice would increase the accuracy of the wave and ocean models used in climate, weather, and sea state predictions. Better weather and sea state forecasts are becoming more important in arctic seas, where ship traffic and other human activity are increasing.

The suitcases

As the satellites' ability to measure waves in ice is still limited, measurements must be retrieved in the field by placing wave buoys out on the sea ice. Commercial wave buoys are expensive and not designed for being placed on the sea ice. This is why Jean Rabault and co-workers from UiO and MET developed a cheaper, open-source instrument as part of a PETROMAKS2 financed project: Small orange suitcases, and recently even smaller watertight plastic cases. In many ways, these cases are not much more than bulky smartwatches, as they contain a small computer, a GPS, and a high-precision accelerometer. In smartwatches, accelerometers are used for counting your steps. In the suitcases, the accelerometers record the vertical movement of the suitcases. Place the suitcases out on sea ice, and the accelerometer will precisely tell us how much and how fast the sea ice moves up and down.

16 suitcases on the ice

The Nansen Legacy has helped fund the 16 suitcases that have so far been put out on the sea ice. In addition, an ultrasonic companion to the suitcases has been mounted on the bow of RV *Kronprins Haakon* to measure waves in both the open ocean and the sea ice. How much the wave height differs between open and ice-covered waters, the scientists were able to nicely measure with help of the four suitcases deployed during the Nansen Legacy cruise in September 2018. Just a few days after the first suitcases had been placed out on the ice, gale-force winds hit. In the open sea, the wave height was over three meters, while the accelerometers in the suitcases showed that the waves underneath the ice were less than a meter. Just how rapidly the waves decrease as they enter the sea ice is a "hot" topic. Therefore, the Nansen Legacy will continue to deploy suitcases out on the ice. ■

> "The data collected are giving us a unique possibility to tune both sea ice drift models and waves in ice parametrizations, which will ultimately help improve weather and sea state forecasts."
>
> *Øyvind Breivik, MET*

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Løken T, **Rabault J**, Thomas EE, **Müller M**, **Christensen KH**, Sutherland G, Jensen A (2020) A comparison of wave observations in the Arctic marginal ice zone with spectral models. ***Atmospheric and Oceanic Physics.*** arXiv:2003.09472v3

Rabault J, Sutherland G, Gundersen O, Jensen A, Marchenko A, **Breivik Ø** (2020) An open source, versatile, affordable waves in ice instrument for scientific measurements in the Polar Regions. ***Cold Regions Science and Technology*** 170: 102955

Interaction with society

The Nansen Legacy is first and foremost a research project. However, the full value of successful research projects depends on its overall impact on society on shorter and longer time scales. To what extent can new knowledge help the society to overcome the challenges posed by a rapidly changing climate and consecutive responses in the ecosystem? The Nansen Legacy interacts with society in several ways, and works towards synthesizing and communicating knowledge and results in a way that facilitates dialog with users also outside the scientific community.

Side events on Arctic Frontiers 2020

Photo: Charlotte Stark

During the Arctic Frontiers conference 2020, the Nansen Legacy organized two side events to address important issues where new knowledge is needed in the northern marine regions.

In the side event “From Nansen Legacy to useful knowledge for society”, scientists and members of the Nansen Legacy Reference group representing industries and governmental organisations presented knowledge and knowledge needs with respect to weather forecasts, ecosystems and fisheries, ecotoxicology, the ice edge and future conditions in the Barents Sea. The other side event asked the question “What does it take to manage fisheries sustainably?”, and the international expert panel discussed critical elements of modern fisheries management including scientific work to understand and monitor marine ecosystems in change, the provision of scientific advice, cooperation between governments on management of transboundary fish stocks, domestic resource management regimes, and robust enforcement practices. Both events were well visited and inspired good discussions.

Contributions to the Arctic Council

Many of the Nansen Legacy participants contribute to synthesis of scientific knowledge through participation in international organisations or working groups. Results and knowledge from the Nansen Legacy are included, where relevant.

Photo: Christian Morel/ christianmorel.net

The Arctic Monitoring and Assessment Programme, AMAP, under the Arctic Council is one of these working groups. Through AMAP, Katrine Borgå (UiO) is part of the AMAP Persistent Organic Pollutants expert group, which has been working on a report summarizing on how climate changes impact contaminants in the Arctic. Borgå has been leading the chapter on food webs, and she included her PhD student, Julia Giebichienstein in the writing process and meetings. This is a good example of how early career scientists can extend network and competence, and become familiar with this kind of international collaborating efforts to compile knowledge across the science community and make the results available for the broader society. ■

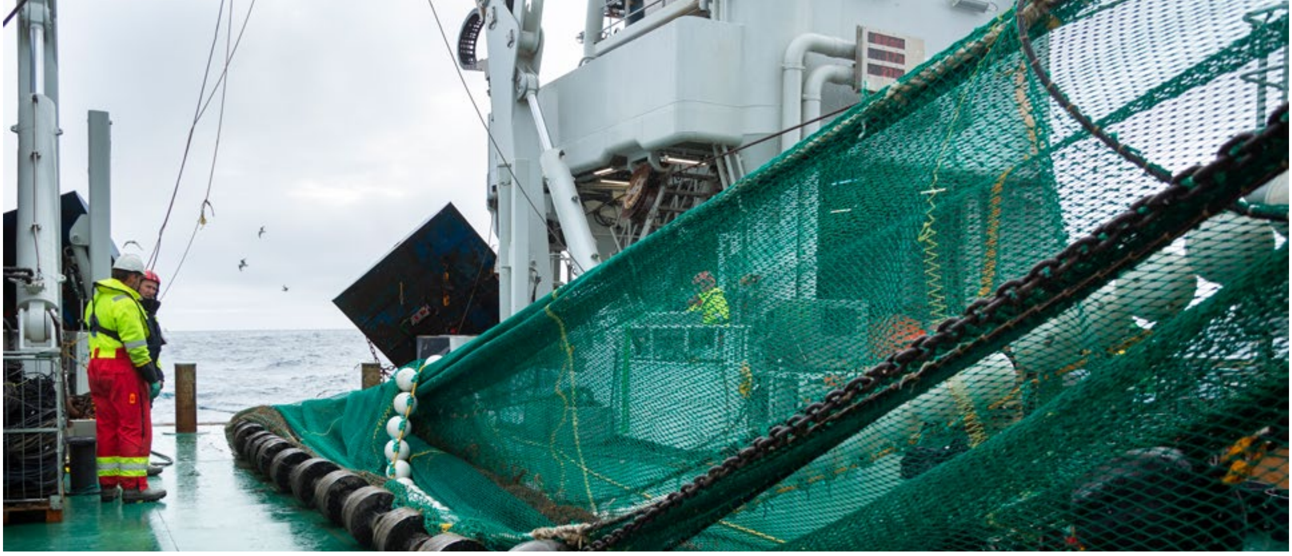

Photo: Christian Morel / christianmorel.net

Can Norway increase its fishing yields while protecting the marine environment?

A growing world population rises marine food demands at the same time as overfishing and marine habitat destruction calls for implementation of a sustainable, ecosystem-based fisheries management. Balanced Harvesting has been suggested as a possible strategy to ensure increased marine food production while preserving marine food webs. What would implementation of a Balanced Harvesting approach mean for Norwegian fisheries in the Nordic and Barents Seas?

Balanced harvesting

Many of today's fisheries target selected species and, within that species, selected sizes. This has resulted in overfishing of many fish species and depletion of large sized fish, both severely altering the structure of marine food webs. Balanced Harvesting has been proposed as a fishing strategy to deal with these problems, while simultaneously maintaining maximum fishing yields. The rationale behind the Balanced Harvesting approach is to diversify our fisheries, diverting them from targeting single species and sizes to fishing on all species and sizes proportionally to the species and sizes' production. In simpler words: Does a species grow fast, fisheries according to a Balanced Harvesting approach should fish relative larger quantities of this species than of a slower growing one.

The Norwegian and Barents Sea

The Norwegian and Barents Seas have been subjected to moderate fishing pressure on individual species for many years. Overall, Norwegian fisheries management scores high on principles of ecosystem-based fisheries management although it largely regulates fisheries on species-level. In a recent study, Nansen Legacy PhD student Ina Nilsen (IMR) and co-workers used an Atlantis end-to-end ecosystem model to investigate the effects of applying a Balanced Harvesting regime to the Norwegian managed fisheries in the Nordic and Barents Seas a region.

Increased fishing yields would need to come from lower trophic levels

The results from the Atlantis ecosystem model showed that implementing a Balanced Harvesting regime in the Norwegian and Barents Seas would only produce marginal increases in total yields of currently commercially exploited stocks, likely because the Norwegian fisheries are already mostly well-managed. However, expanding the fishery to include species that are not commercially exploited today did produce higher yields, especially on lower trophic levels. The study also shows that Norwegian fisheries are well monitored and managed, and already score relatively high in terms of a balanced fishing pattern, with fishing levels on most species close to their respective maximum sustainable yields. This suggests that there are only limited gains for implementing a Balanced Harvesting regime on the current commercial stocks in the Nordic and Barents Seas a region. ■

> "This is the first study applying an ecosystem model in the Norwegian and Barents Seas exploring how a Balanced Harvesting strategy could impact fishing yields, and a contribution to a wider discussion on fisheries management."
>
> *Ina Nilsen, IMR*

Reference:
Nilsen I, Kolding J, **Hansen C**, Howell D (2020) Exploring balanced harvesting by using an Atlantis Ecosystem Model for the Nordic and Barents Seas. Frontiers in Marine Science 7:386. doi: 10.3389/fmars.2020.00386

Societal impact

The overarching goal for the Nansen Legacy project is to provide a better scientific basis for the sustainable management of the northern Barents Sea and the adjacent Arctic Ocean. Some examples below illustrate advances in this respect within the project, as well as pointing to processes that have implications also for the global climate.

Safe guiding AUV operations

Autonomous under water vehicles (AUVs) play an increasingly important role in marine research and offshore exploration. Long-range AUV mission come at a risk of losing the vehicle due to abrupt changes in the operating environment. A new method provides operators of AUVs with an overview of the environmental impact of the AUV operation. It can work as a guide on how to choose the mission path before the operation, and it provides the vehicle and operator with a dynamic risk indicator, which can support the AUV's decision-making.

Collecting data for improving sea state alerts

Increasing human activity in ice-covered waters calls for improved sea state alerts in arctic seas. This requires an improved understanding of how sea ice dampens waves, an information that cannot be retrieved satisfactorily from satellite measurements. Therefore, the Nansen Legacy is part of deploying newly developed wave buoys out on the ice. The data collected are giving a unique dataset to tune both sea ice drift models and waves-in-ice parametrizations, which will ultimately help improve weather and sea state forecasts.

Satellite-aided monitoring for oil slicks in ice-covered waters

Increasing human activities in arctic seas increase the risk for oil spills in ice-covered waters. Yet, the technology routinely used to monitor for marine oil spills in the World's oceans could so far not distinguish between mineral oil slicks and newly formed sea ice. This limitation has now been rendered by the development of a new method, using synthetic aperture radar (SAR) imagery retrieved from airborne or satellite-borne radars. This allows surveilling of potential oil spills in marine areas where newly formed sea ice may occur, such as e.g., within the marginal ice zone.

Contributing to discussion on sound fisheries management

A sound fisheries management aims at maximizing the harvest over time, based on a sustainable ecosystem. A model study comparing an alternative management strategy, Balanced Harvesting, to the present-day system, conclude that the currently exploited commercial stocks are well managed. The model also suggests that there may be potential in presently non-commercial species. At the same time, the present investigations of the Barents Sea ecosystem reveal complexity in responses to the changing climate on individual and population level, as studies of the Polar cod indicate. It is therefore important to increase our knowledge of non-commercial species, their role in the ecosystem and their responses to environmental changes.

Testing predictability of ocean productivity and CO2 uptake

Ocean biogeochemistry, such as primary productivity and CO_2 uptake, is an important factor in the global climate system. Increasing the predictability of ocean carbon uptake in climate models helps in understanding the complex interplay between the oceanic and atmospheric forces at play. Model based experiments revealed that the predictability of ocean primary production and CO_2 fluxes are insensitive to the biogeochemical initial state, but relate to the predictability of the mixed layer, which was shown to be less predictable than many other physical drivers. Hence, future studies need to target the predictability of the mixed layer depth.

Improved understanding of physical processes

One of the key factors and least understood processes regulating the ocean water structure, sea ice dynamics and productivity is linked to mixing of the upper ocean. Mixing regulates the distribution of heat as well as nutrients, and is driven by large as well as smaller scale processes, like turbulence. The Nansen Legacy uses autonomous underwater vehicles (AUVs) and gliders in addition to ship-based measurements to map ocean turbulence at high-resolution over larger geographic areas. So far, observations from the shelf north of Svalbard emphasize the role of tidal dynamics in generating turbulent mixing.

The Barents Sea in the global climate system

Processes in the Barents Sea and along the slope north of Svalbard play a role also outside the region, with impact on the Arctic Ocean as well mid-latitude regions. Atmospheric teleconnections and the large-scale oceanic circulation connect the Barents Sea with the World and vice versa. Time series of hydrographic and meteorological conditions provided the basis for studies on the interconnection of the Barents Sea with the rest of the World. They demonstrated the effect of air-sea heat fluxes on deep-water formation and how the Atlantic atmospheric jet stream influences e.g., the path of cyclones and storm tracks.

Photo: Christian Morel / christianmorel.net

Detecting mineral oil slicks in ice covered seas from space

The thinning and retreat of the arctic sea ice has led to increased human presence in Arctic seas. Marine traffic is most likely to increase in the future, as are activities such as fishing, oil and mineral exploitation. All these activities increase the risk for oil spills in ice-covered waters. Yet, the technology used to monitor for marine oil spills in the World's oceans is not yet applicable for ice-covered seas. A new study presents a first approach to overcome this limitation.

From whales and the challenge to detect oil spills

Tooth whales echolocate, meaning that they send out loud clicking sounds via special nasal structures and listen for echoes bouncing off objects. That helps the whales to navigate and to find food. Humans use the backscatter of sound waves but also from visible light and longer radio waves for navigation and investigation of the world. Airborne and spaceborne radars surveille our planet by sending and receiving centimeter long waves. This technology can see through clouds and can image the Arctic even during the polar night. This technology has been widely used to detect and monitor spills of mineral oil at sea. Different methods have been applied to distinguish clean and oil-infested sea surfaces with help of radar signals, many of which use the shape of the oil slicks. In ice-covered waters, this approach gives rise to two problems. Firstly, ice floes and leads alter the shape of oil slicks, making it impossible to apply established protocols. Secondly, radars have problems distinguishing between newly formed sea ice and oil at sea.

From wiggling waves and 3D glasses

In a recent study, researchers from UiT in collaboration with the NASA Jet Propulsion Laboratory examined a new method to discriminate oil slicks and newly formed sea ice using synthetic aperture radar (SAR) imagery. Their approach takes advantage of the fact that radio waves wiggle up and down, and left and right, as they travel. The wiggling of the waves is called polarization, a phenomenon which 3D glasses use to give us the illusion of a three-dimensional space. The polarization of radar signals can also be used to deduct information about the properties of an object, as the objects properties will influence the polarization of the waves' backscatter. Using radars with multiple frequencies increases the information deductible from the polarized reflections.

Polarization reliably separates oil slicks and newly formed sea ice

To check if multifrequency polarimetric information from SAR images could separate between oil slicks and newly formed sea ice, Johansson et al. 2020 analyzed SAR images taken during the OOW2015 exercise in the North Sea, and an oil seep in the Gulf of Mexico in 2016, which generated images of oil slicks in ice-free waters. They compared those to SAR images of newly formed sea ice from the Beaufort-Chukchi Sea and the Barents Sea. The latter was in part generated during the Nansen Legacy seasonal cruise Q4 in December 2019. The comparison demonstrated that oil slicks and new ice have different polarimetric backscatter, and consequently, the difference in polarization can be used to distinguish between these two different surfaces. ■

> "The results of the study provide an approach to distinguish oil slicks from newly formed sea ice, which might be of special interest should and oil spill occur within the marginal ice zone."
>
> *Camilla Brekke, UiT*

Reference:

Johansson AM, Espeseth MM, **Brekke C**, Holt B (2020) Can mineral oil slicks be distinguished from newly formed sea ice using synthetic aperture radar? IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 13: 4996-5010. doi.org/10.1109/JSTARS.2020.3017278

Not all Nansen Legacy scientists need to go to sea. Early career scientists Elina Efstathiou and Filippa Fransner at the University of Bergen are using mathematical models to investigate the present and future states of the physical and biogeochemical environment in the Arctic.

Photo: Marius Årthun


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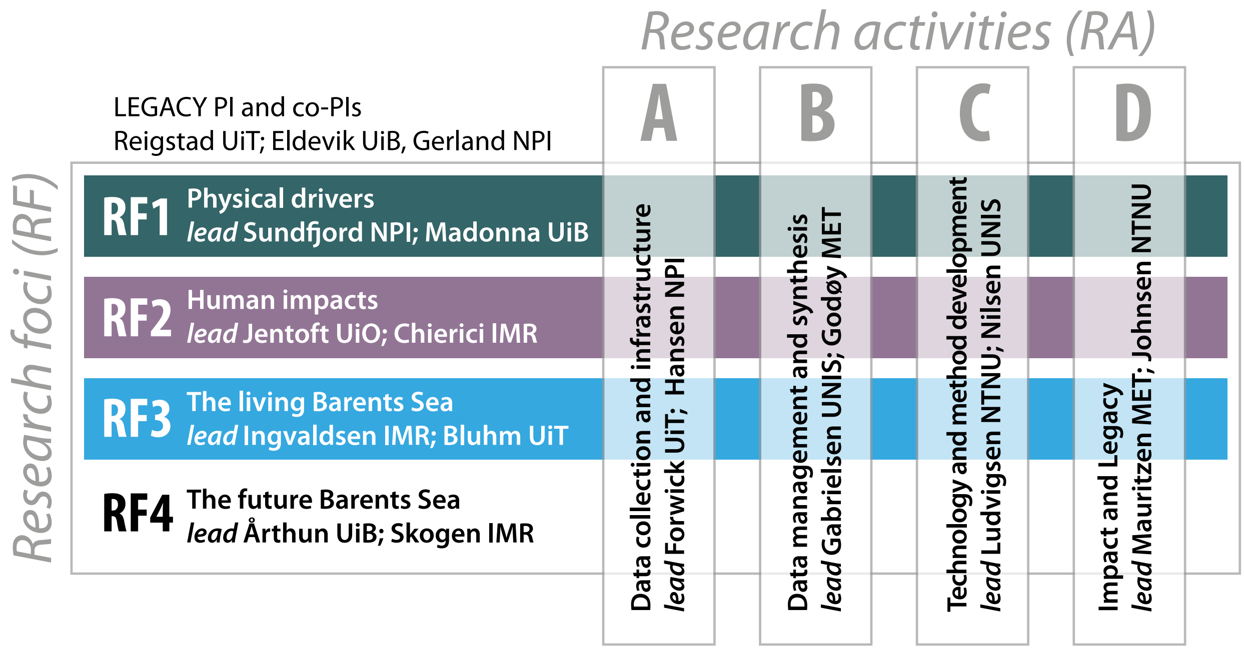
Organisation

The Nansen Legacy is a collaboration between ten Norwegian research institutions, currently involving over 200 project members. Members include PhD students, postdoctoral fellows, researchers, technicians, engineers and communication advisers. In addition to the scientific leadership, the project has a Board, as well as a Scientific Advisory board.



The Research Foci (RF1-4) represents "what" science the Nansen Legacy is investigating, and the Research Activities "how" (A-C), including impact and legacy in the public domain (D).

Project leaders

Marit Reigstad, UiT

Prof. Reigstad is the principal investigator (PI) of the Nansen Legacy. She is a marine ecologist interested in connectivity, including physics and biology, surface and deep waters, and regional connections. She has led several interdisciplinary projects and expeditions on Arctic marine ecosystems, and is active in science communication. Reigstad has been involved in international science planning since 2004, through ICARP and IASC. She serves on Liason- and evaluation panels and scientific advisory boards.

Tor Eldevik, UiB

Tor Eldevik is co-PI of the Nansen Legacy and the Head of Department of the Geophysical Institute, UiB. Eldevik generally explores the northern seas' role in past, present, and future climate, using a combination of theory, observations, and numerical models. The combination is also Eldevik's approach in communicating his research and other aspects of climate change to students and the general public. Present commissions of trust include contributing to the European Academies' Science Advisory Council (EASAC) and member of the Research Council of Norway's Portfolio Board for Climate and Polar Research.

Sebastian Gerland, NPI

Dr. Gerland is co-PI of the Nansen Legacy. He is currently working with sea ice physics research and monitoring in the context of Arctic climate research. Beyond his involvement in the Nansen Legacy, he is leading and participating in other national and international projects, including the Norwegian Polar Institute's long-term Arctic sea ice monitoring, and projects funded by the Research Council of Norway (e.g. HAVOC-MOSAiC and CIRFA SFI). Gerland is also active in climate assessments (currently IPCC's 6th assessment report and the NOAA Arctic report card).

RF1 Physical drivers

Arild Sundfjord, NPI

Erica Madonna, UiB

The Barents Sea is a significant gateway with inflow of Atlantic water to and Arctic water from the rapidly changing Arctic Ocean. A firm understanding of the physical climate system in this region is a fundamental building block for any sustainable management, and prognostic models for the Barents Sea and the adjacent Arctic. *Objective:* Determine contemporary and historical environmental conditions and internal regulation mechanisms, and based on this improve the understanding of physical system response to environmental changes.

RF2 Human impacts

Sissel Jentoft, UiO

Melissa Chierici, IMR

Arctic areas are exposed to climate change as well as other human influences, such as ocean acidification, pollution, and commercial fisheries. *Objective:* Improve our understanding of how human activities influence the northern Barents Sea ecosystem.

RF3 The living Barents Sea

Randi Ingvaldsen, IMR

Bodil Bluhm, UiT

Biodiversity, ecosystem functioning, and environmental forcing are inherently and intricately linked in any ecosystem, with their relationships shaped by region, habitat and temporal dynamic. *Objective:* Build critical understanding of how organisms in the northern Barents Sea ecosystem and adjacent slope respond to current and changing environmental conditions on the species and community levels by identifying characteristic communities, delineating the relevant environmental forcing factors that structure these communities across seasons and habitats, estimate their production and rate-limiting factors, and detail trophic and other ecosystem linkages.

RF4 The future Barents Sea

Marius Årthun, UiB

Morten Skogen, IMR

The sustainable management of resources and environment is fundamentally about foresight. It depends critically on our capacity to observe, understand and eventually predict the transitions between past, present and future states of weather, climate, and the marine ecosystem. *Objective:* Assess the state, predictability, and associated uncertainties of the Barents Sea weather, climate, and ecosystem.

RA-A Data collection and infrastructure


Matthias Forwick, UiT


Håvard Hansen, NPI

The Nansen Legacy will carry out multi-disciplinary research using extensive ship-based field expeditions. This fieldwork is based on a coordinated use of the Norwegian research vessels, particularly the new Norwegian ice-going research vessel RV *Kronprins Haakon*. *Objective:* Facilitate, coordinate, and integrate the collection of new observational data, proxy data, and modeling output across the *Nansen Legacy* project.

RA-B Data management and synthesis


Tove Gabrielsen, UNIS/UiA


Øystein Godøy, MET

Structured data management is a pre-requisite for data exploitation; the act of exploration of the full potential of scientific data as individual datasets, in a discipline specific context, and in an interdisciplinary perspective. *Objective:* Ensure longterm preservation of all relevant data, with unified, open data access through services that provide for simplified data exchange and responsible data reuse, including proper attribution.

RA-C Technology and method development


Martin Ludvigsen, NTNU


Frank Nilsen, UNIS

Enabling technology for mapping and monitoring of extreme environments is essential for modern future management and sustainable utilization of the Barents Sea. Arctic conditions require a high degree of autonomy and integrated observation systems to reduce operation time and weather dependency, and to enable measurements in all seasons. *Objective:* Study and develop reliable and robust autonomous platform solutions for smarter measurements and sampling for detection and analysis, to improve modeling based on remote sensing with impacts on the ecosystem or human activity in the Barents Sea.

RA-D Impact and legacy


Cecilie Mauritzen, MET


Geir Johnsen, NTNU

A major task for the Nansen Legacy is to promote interest for and increase the general knowledge about Arctic marine systems. To accomplish this, it is necessary to reach out to the scientific community and the general public, to establish dialogue with users and stakeholders, to educate the next generation of scientists, and to enhance the focus on innovation as potential products of basic science. *Objective:* Ensure outstanding national and international impact from the research carried out, to ensure a lasting legacy of the project, and to enhance the benefit and relevance to society.

Nansen Legacy Annual meeting, October 2019. Photo: Magne Velle

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Timo Vihma	Finland	Finnish Meteorological Institute

Nansen Legacy at work.
Large photo: Christian Morel / christianmorel.net
Small photos, from left to right: Algot Peterson, Maria Digernes, Algot Peterson, Christian Morel / christianmorel.net

Publications

The Nansen Legacy has so far published 43 peer-reviewed articles in renowned, high-ranking scientific journals, five of them in Nature and Science journals. The cross-institutional spirit of the Nansen Legacy is reflected in the publications coming out from the project. Almost 60% of the articles have authors from two or more Nansen Legacy consortium partners. Additionally, half the publications include international partners on the author list. These include scientists from 20 different countries and 64 different research institutions outside of Norway. In addition to the 10 Nansen Legacy consortium institutions, the project's publications are co-authored by scientists from seven Norwegian non-Nansen Legacy institutions. In total, 82% of the Nansen Legacy publications include authors from two or more national and international institutions, reflecting the collaborating efforts of the project participants.

Peer-reviewed publications

2020

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SWL 3T

Oceanographic moorings secured in-situ measurements from the Barents Sea also in 2020, when COVID-19 related restrictions limited field activities.
Photo: Christine Gawinski

The Nansen Legacy in numbers

6 years

The Nansen Legacy is a six-year project, running from 2018 to 2023.

1 400 000 km² of sea

The Nansen Legacy investigates the physical and biological environment of the northern Barents Sea and adjacent Arctic Ocean.

280 people

Currently, there are about 230 researchers working with the Nansen Legacy, of which 73 are early career scientists. In addition, 50 persons are involved as technicians, project coordinators, communication advisers and board members.

10 institutions

The Nansen Legacy unites the complimentary scientific expertise of ten Norwegian institutions dedicated to Arctic research.

>10 fields

The Nansen Legacy includes scientists from the fields of biology, chemistry, climate research, ecosystem modelling, ecotoxicology, geology, ice physics, meteorology, observational technology, and physical oceanography.

>350 days at sea

The Nansen Legacy will conduct 15 scientific cruises and spend more than 350 days in the northern Barents Sea and adjacent Arctic Ocean between 2018 and 2022. Most of these cruises are conducted on the new Norwegian research icebreaker RV *Kronprins Haakon*.

50/50 financing

The Nansen Legacy has a total budget of 740 million NOK. Half the budget comes from the consortiums' own funding, while the other half is provided by the Research Council of Norway and the Ministry of Education and Research.

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