

Sentinel
North



SHEDDING LIGHT ON THE NORTH
ENVIRONMENT | HEALTH | INNOVATION

ACTIVITY REPORT
2020-2021



UNIVERSITÉ
LAVAL

Through Sentinel North, Université Laval encourages the convergence of expertise, transformative research, the development of new technologies, and the training of a new generation of interdisciplinary researchers working to improve our understanding of the northern environment and its impact on people and their health.



The program is made possible thanks, in part, to significant funding from the Canada First Research Excellence Fund.



Sentinel North is financially supported by the Fonds de recherche du Québec.



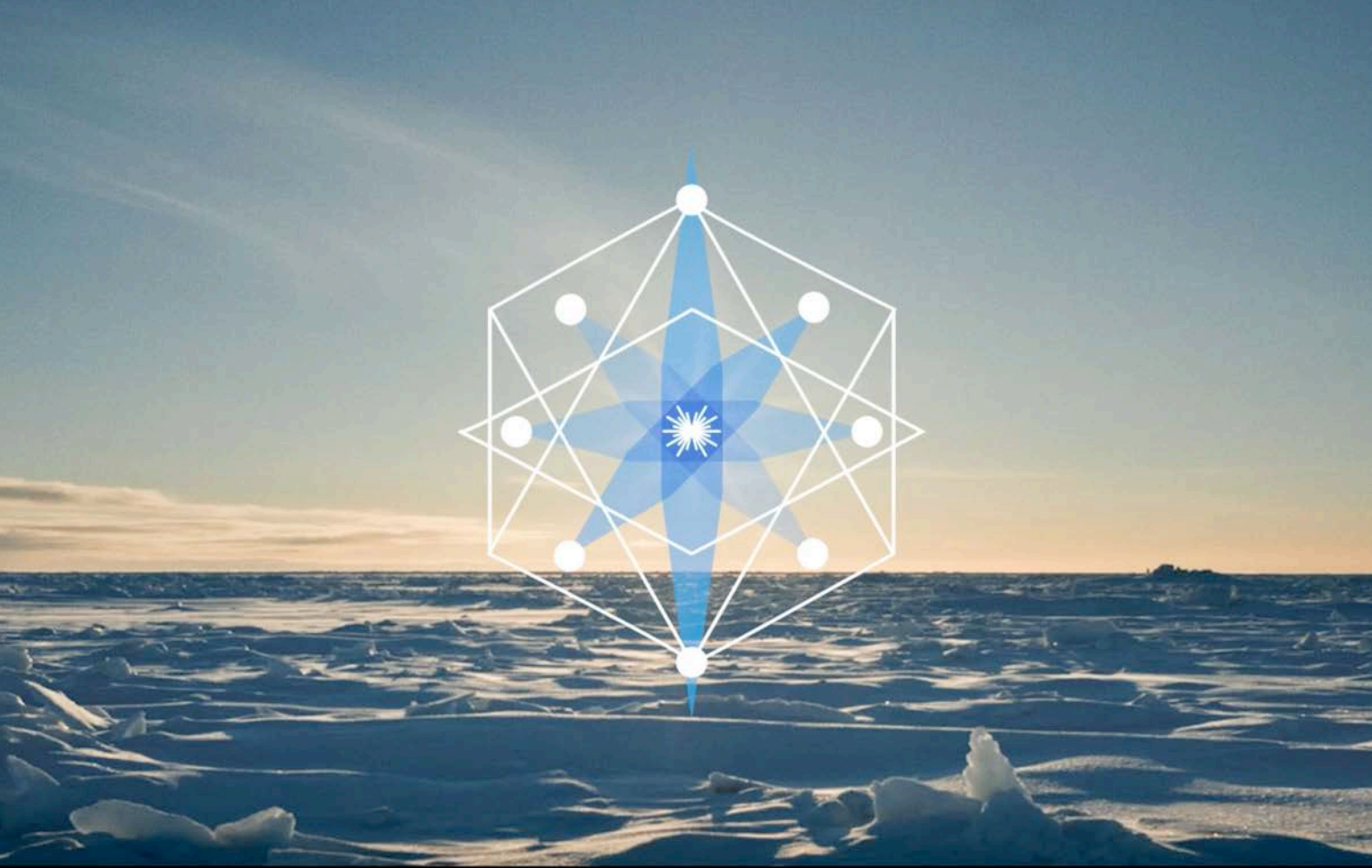


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Photo: Fritz Mueller

Vision

To shed light on the northern environment and its impact on humans by means of innovative new technologies and interdisciplinary research initiatives in support of sustainable health and development.

Message from management

Sentinel North was undoubtedly impacted by the pandemic that affected all aspects of society in 2020-2021. Laboratory work interrupted in March gradually resumed in May 2020, but field campaigns were seriously compromised, especially in northern regions that remained inaccessible. The global containment also hampered many of our international collaboration, recruitment, and training efforts.

Despite these unprecedented constraints, this report is a testament to the agility of the administrative center and our community, as they quickly adapted the deployment of their activities to this new virtual world. Among the achievements in 2020-2021:

- Fourteen new interdisciplinary teams joined the research program in fall 2020 following a \$9.5 million major call for proposals. An incentive to involve early career faculty or professors from underrepresented groups has paid off, with a majority of the new projects led or co-led by women and young academics.
- Three Sentinel North partnership research chairholders were recruited in collaboration with public and private organizations.
- Our teams published over 100 peer-reviewed articles, bringing the number of articles published since 2017 to more than 330.

- A rich program of workshops, seminars, and online training initiatives attracted over 800 participants from 65 universities.
- Thirteen excellence scholarships were granted to outstanding graduate students and postdoctoral fellows.
- New strategic agreements between Université Laval and two major French universities, Université PSL and Sorbonne Université, will increase collaborations in many of Sentinel North's research areas.

With the gradual opening of borders and northern regions, we are preparing with great enthusiasm for the upcoming resumption of fieldwork, experiential training, international conferences, and face-to-face exchanges with our valued partners in the North and South.

Our isolation over the past few months has illustrated more than ever the irreplaceable value of mobility and in-person contact for the research community and for the pursuit of our mission to bridge disciplines and push the frontiers of knowledge towards a better understanding of the northern environment and its impact on health.



Eugénie Brouillet
Vice Rector,
Research and Innovation
Chair, Sentinel North Steering
Committee



Martin Fortier
Executive Director,
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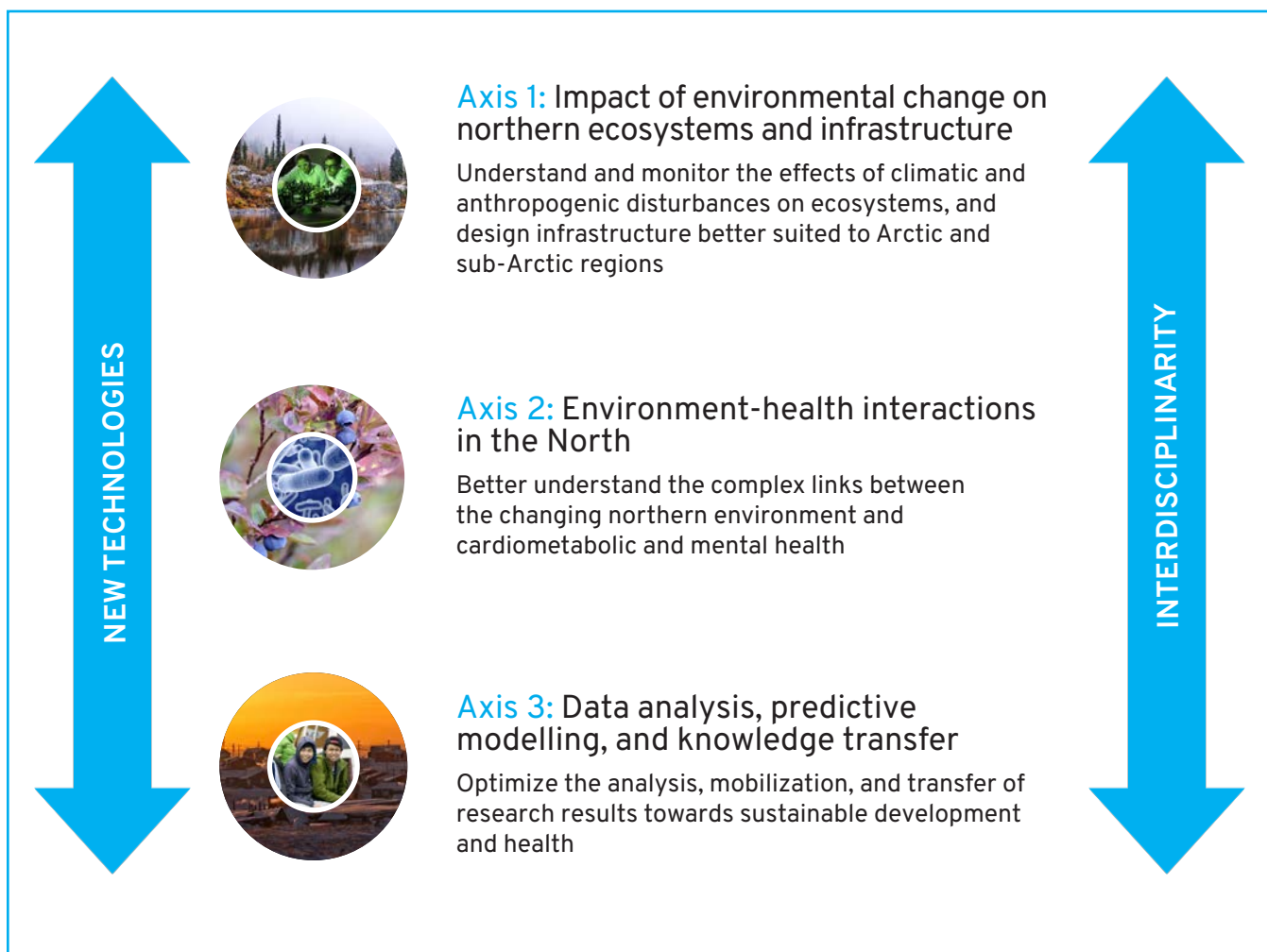
Yves De Koninck
Scientific Co-Director,
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Marcel Babin
Scientific Co-Director,
Sentinel North
Laureate of the CERC in
Remote Sensing of Canada's
New Arctic Frontier

Program overview

In the face of accelerating climate change and socioeconomic development in the Arctic and sub-Arctic, the Sentinel North research program helps generate the knowledge needed to monitor and prepare for environmental changes at multiple levels, from microbes to ecosystems. Sentinel North’s conceptual framework and priority research axes drive the program’s research, training, and partnership initiatives.





Some statistics, from 2017 to 2021

ADVANCING RESEARCH
THROUGH CONVERGENCE

70+



interdisciplinary teams

165+

professors from
40 departments
at Université Laval

TRAINING A NEW GENERATION
OF SCIENTISTS FOR THE NORTH

11M\$+



invested in grants
and training

508



graduate students
and postdoctoral fellows

DISSEMINATING RESEARCH
AND INNOVATION RESULTS

2100+ scientific
communications

330+ peer-reviewed
publications

2.24 index of highly
interdisciplinary
publications

1.00 World benchmark

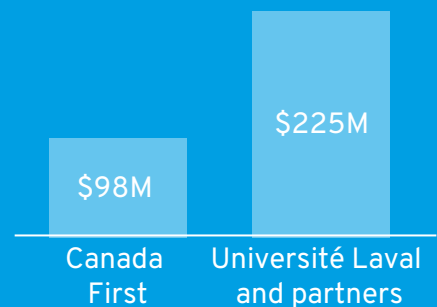
FOSTERING PARTNERSHIPS AND COLLABORATION

350+
partners in Canada
and abroad



2.3:1

mobilized and
anticipated
research
funding



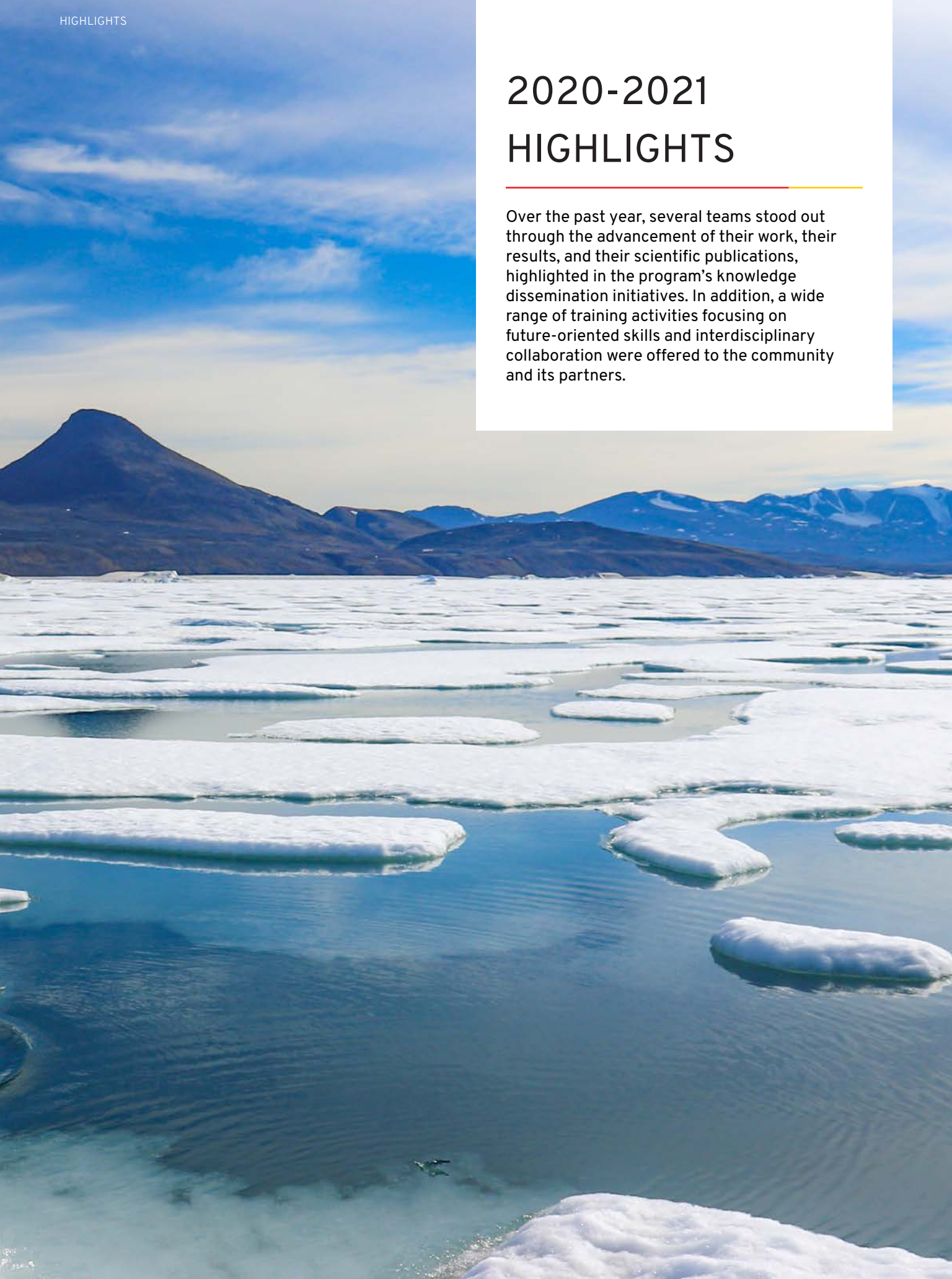


Professors Alexander Culley (photo) and Warwick Vincent lead a research team that studies microbiomes in the extreme environments of Canada's High Arctic: glaciers, ice shelves, lakes, soils, permafrost, and ice-covered seas. Research is focused on the microbiomes' impact on ecosystems and human health.

Photo: Denis Sarrazin

2020-2021 HIGHLIGHTS

Over the past year, several teams stood out through the advancement of their work, their results, and their scientific publications, highlighted in the program's knowledge dissemination initiatives. In addition, a wide range of training activities focusing on future-oriented skills and interdisciplinary collaboration were offered to the community and its partners.



Research

Sentinel North's teams are joining forces to generate knowledge and technological advances leading to a better understanding of the changing northern environment and its impact on health. Over the past year, its teams have delivered more than 350 scientific papers and publications, including more than 100 peer-reviewed articles in leading journals, most of which are highly interdisciplinary and available in open access.



Selected highlights and publications

- Identification of 351 viral populations from a thermokarst lake, including novel phages and prophages: diversity increases in summer and is unexpectedly similar to other viral populations from remote permafrost thaw lakes. ([Girard et al. 2020. *Viruses*.](#))
- Bacteria in the ice pack are under stress as the ice melts, leading to a reduction in bacterial activity associated with an increase in mortality (up to 75% of bacteria). ([Amiriaux et al. 2020. *Elementa: Science of the Anthropocene*.](#))
- The first continuous measurements of limnological properties show significant ecological disturbance and year-to-year variability in Canada's northernmost lake, one of the last in the High Arctic to lose its perennial ice cover. ([Bégin et al. 2021. *Limnology and Oceanography*.](#))
- Deployment of an underwater imaging system under the pack ice: copepod morphology and posture vary with sea ice dynamics and spring phytoplankton growth. ([Vilgrain et al. 2021. *Limnology and Oceanography*.](#))
- Study of the water column of a lake in the Canadian High Arctic: physical, chemical, and biological properties vary greatly with depth and are indicators of sensitivity to climate change. ([Bégin et al. 2021. *Scientific Report*.](#))
- Decreased hunting activity during COVID led to improved spring fattening of greater snow geese, as well as changes in their behaviour and their use of the environment. ([LeTourneux et al. 2021. *Biological Conservation*.](#))
- Fabrication and characterization of an innovative fibre-optic curvature sensor with increased sensitivity and flexible design for use in a wide range of applications. ([Boilard et al. 2020. *Optics Express*.](#))
- Association between income inequalities and the place of private financing in health: increases in inequalities can accentuate the proliferation of private clinics and the departure of physicians from the public system, worsening the problem of access to care in certain communities, including northern communities. ([Isabelle et al. 2020. *Health Economics*.](#))

Selected highlights and publications (continued)

- Gut microbiota and dietary fatty acid intake determine endocannabinoidome signalling beyond the effect of body fat. ([Castonguay-Paradis et al. 2020. Scientific Reports.](#))
- Use of the intestinal microbiota to reduce the levels of circulating pollutants in the context of obesity: thanks to a prebiotic, animals' metabolic health improves and the relative quantity of pollutants decreases. ([Choi et al. 2020. Food and Chemical Toxicology.](#))
- Epigenetic changes in the brains of suicide victims promote the expression of a non-coding RNA that controls the expression of impulsive and aggressive behaviours in humans and mice. ([Labonté et al. 2020. Molecular Psychiatry.](#))
- A method for solving problems limiting ultrafast laser inscription in silica glass optical fibres in the design of a sensor for studying cardiometabolic diseases and mental illnesses related to gut microbiota. ([Lapointe et al. 2020. OSA Continuum.](#))
- Blood levels of perfluoroalkyl acids are twice as high in pregnant women in Nunavik than elsewhere in Canada: the importance of better regulating these contaminants to protect the exceptional quality of traditional foods in Nunavik. ([Caron-Beaudoin et al. 2020. Environment International.](#))
- Variations in phytoplankton lipid synthesis in the Canadian Arctic: the taxonomic composition, the environment, and the formation of subsurface chlorophyll maximum layers play a key role in the production of essential fatty acids transferred through food chains. ([Marmillot et al. 2020. Frontiers in Environmental Science.](#))
- Diatom microalgae (the main primary producers in the Arctic) respond differently to light variations and transitions to darkness depending on their living environment. ([Croteau et al. 2020. Limnology and Oceanography.](#))
- Marine food chain: phytoplankton continues to grow even during the Arctic winter, despite the near-total absence of light. ([Randelhoff et al. 2020. Science Advances.](#))





Selected highlights and publications (continued)

- Development of an online decision support tool for the collaborative planning of sustainable and resilient northern villages in Nunavik. ([Living in Northern Quebec. *Pinasuqatigiitsuta.org*](#))
- New method of using spatial ecology to reduce human-wildlife conflicts. ([Fortin et al. 2020. *Frontiers in Sustainable Food Systems.*](#))
- Increased risk of caribou mortality due to indirect effects of spruce budworm outbreaks: forest defoliation and salvage logging affect trophic interactions in large mammals. ([Labadie et al. 2021. *PNAS.*](#))
- Bacterial hosts of unknown phages in various environments can be predicted using a bioinformatics method that takes advantage of the information contained in CRISPR-Cas systems. ([Dion et al. 2021. *Nucleic Acids Research.*](#))
- Development of a web application for using a deep-learning-based method to generate high-quality starting points for optical design. ([Côté et al. 2021. *Optics Express.*](#))



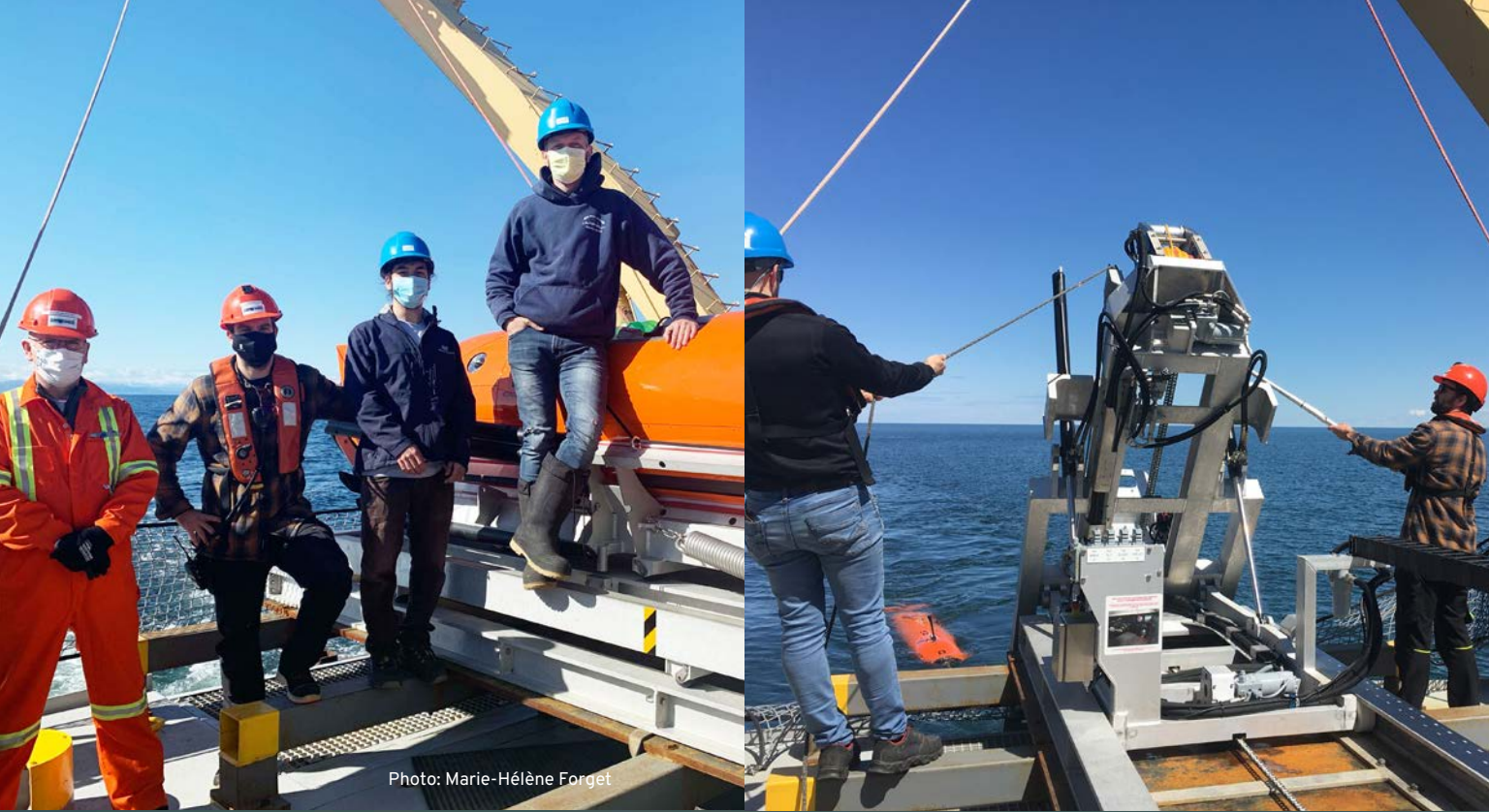


Photo: Marie-Hélène Forçet

As part of the “Characterization of underneath sea-ice light field variability in the Arctic Ocean using underwater and aerial autonomous vehicles” project (Marcel Babin, Université Laval; Jørgen Berge, UiT The Arctic University of Norway), a team successfully deployed a *Hugin 1000* autonomous underwater vehicle in October 2020 and May 2021 from the *Coriolis II* research vessel in the St. Lawrence Estuary and Gulf in preparation for an upcoming mission under the Arctic ice pack.

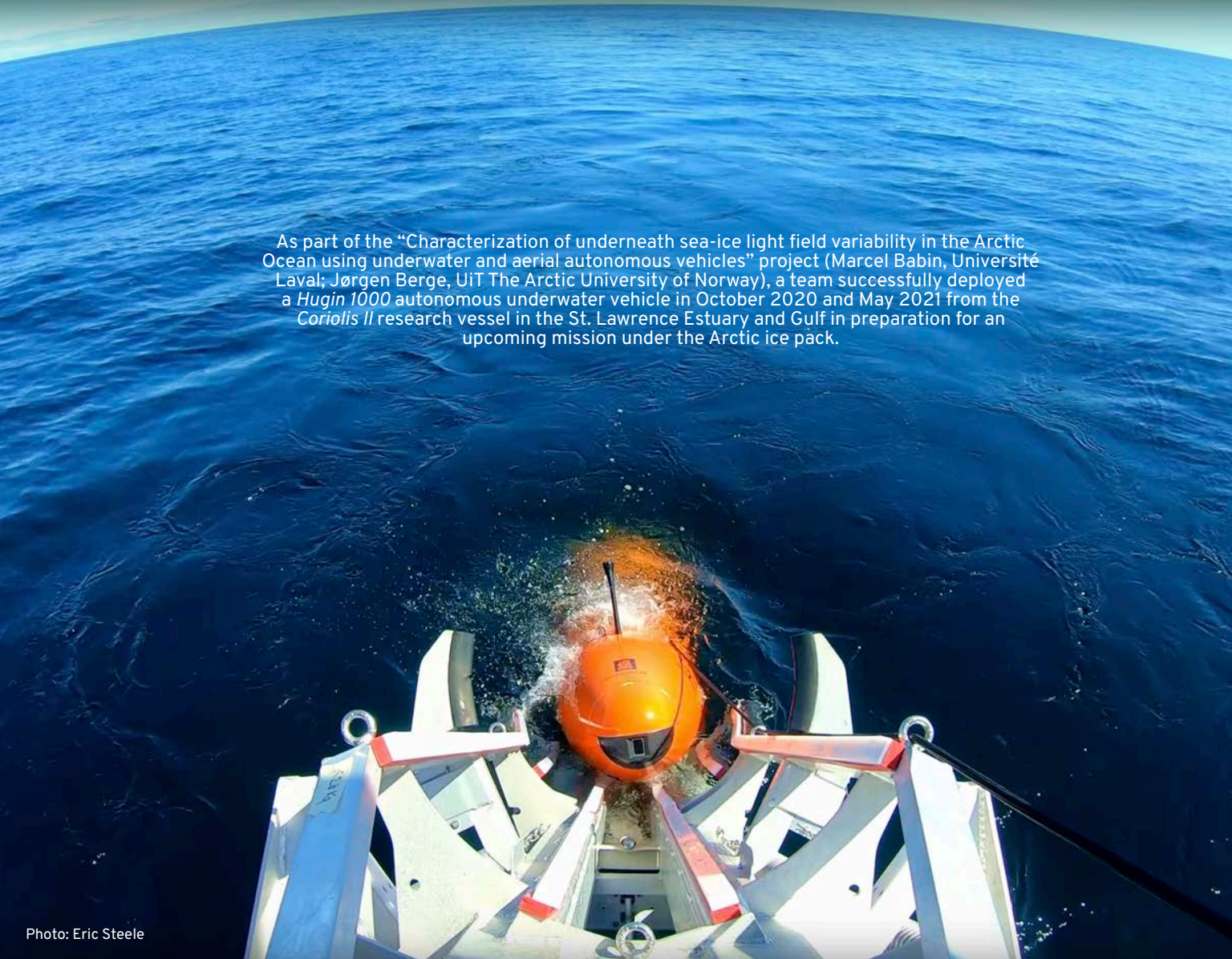


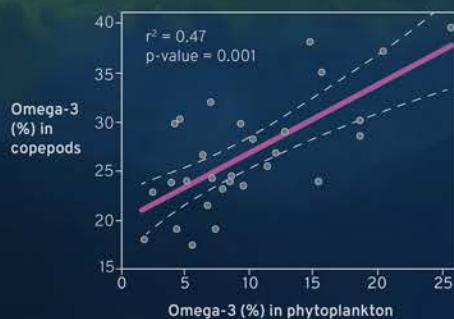
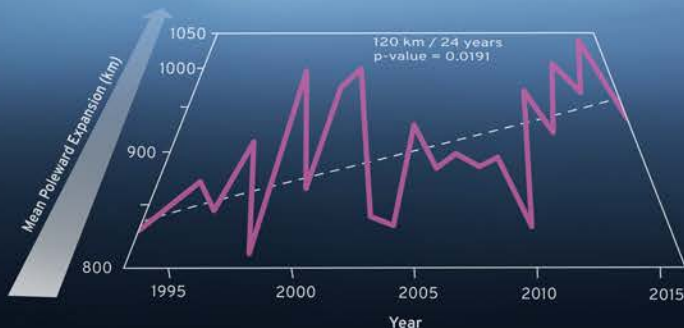
Photo: Eric Steele

HUMAN HEALTH - ENVIRONMENT INTERACTIONS IN THE NORTH

Arctic and subarctic regions are affected by major environmental changes that have direct consequences on marine and terrestrial ecosystems and on the health of populations that rely on their services. Early results from Sentinel North are shedding light on the complex interactions between human health and the environment in the North through convergence research and the development of new approaches and innovative technologies.

A Changing Physical Environment

The significant increase in North Atlantic current surface velocities through the European Arctic Corridor over the last 24 years has led to the poleward expansion of *Emiliana huxleyi*, a phytoplankton tracer of temperate ecosystems¹. This physical and biological "Atlantification" of the Arctic Ocean could affect the entire marine ecosystem by shifting species distribution and impacting energy transfer to higher trophic levels.



Determinants of Plankton Lipids

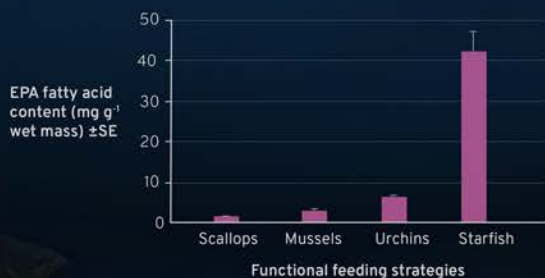
Changes in the physicochemical environment influence the essential fatty acid composition of marine phytoplankton largely through shifts in species assemblages². These changes in fatty acids, including omega-3, propagate up the food web via a fairly close trophic coupling between phytoplankton and their zooplankton grazers³.



The lipid-based flux of energy is key in the Arctic and subarctic marine food webs.

Energy Transfer to Higher Trophic Levels

In Nunavik, benthic organisms with various feeding strategies exhibit differences in nutritional value, with higher trophic levels, such as the sea star, presenting higher fatty acid concentrations⁴. Preliminary results also indicate that the nutritional value of arctic charr, as measured by concentrations of omega-3 in the flesh, varies by region and is possibly linked to differences in diet⁵.





Towards a New Detection Tool

The synthesis of a new fluorescein-based thionocarbonated dye and development of a Hg^{2+} -responsive probe marks a crucial step forwards designing reliable and effective portable sensing tools for mercury and other contaminants in country foods⁶.

Marine Food and Human Health

Selenoneine is the major selenium species in beluga mattaag. It is also found in high concentrations in the red blood cells of the Inuit in Nunavik and is positively correlated to their consumption of this highly praised country food⁷. One hypothesis under investigation is that selenoneine may protect from methylmercury toxicity by increasing its demethylation in red blood cells.

Contaminants can be transported to the Arctic through long-range atmospheric and oceanic transport and accumulate in predatory fish, birds and marine mammals.

Environment and the Gut-Brain Axis

A novel optogenetics zebrafish animal model was developed to investigate the impacts of environmental contaminants and ongoing nutritional changes on the gut-brain interactions and health⁸. Harnessing innovations in biophotonics technologies, the model enables monitoring and controlling microbial colonization of the gut, while assessing neurotoxicity, brain cell development, and circuit function.

Zebrafish

Training and knowledge dissemination

A RICH PROGRAM OF TRAINING ACTIVITIES

In response to the pandemic's impact on its experiential activities and training program, Sentinel North quickly set up a dozen virtual activities of all kinds, designed to address the themes of its research program and aimed at developing future-oriented skills. These workshops and schools, offered to students, professionals, and researchers, have led to enriching interactions and new collaborations.

800+ PARTICIPANTS FROM
65 UNIVERSITIES
IN 2020-2021

Some training activities in 2020-2021


- Designing your research funding strategy
- Open science and the pandemic
- Promote your research through the media
- Science communication workshop
- Data visualisation in research
- Social media and research
- Complex Networks Winter Workshop
- Indigenous Engagement Workshop
- Activity on interdisciplinary collaboration
- Producing a high-quality scientific video
- Oral communication in research

SPOTLIGHT ON EMERGING RESULTS

Sentinel North has launched a series of scientific conferences to promote early results and the impact of innovative, interdisciplinary research. Two initial conferences were held in the spring of 2021, demonstrating the complex interactions between the environment and health in the North:

- **Innovative approaches to studying the impact of snow on northern ecosystems**
Martin Bernier and Gilles Gauthier (Université Laval)
- **When Northern clinical priorities and cutting-edge research converge: mental health**
Caroline Ménard and Richard Bélanger (Université Laval)

[Watch the conferences](#)



INTERDISCIPLINARY COLLABORATION AT THE HEART OF THE PROGRAM

The interactive workshop on interdisciplinary collaboration, organized in partnership with Université Laval's Chantiers d'avenir, was held in November 2020. Professors Philippe Archambault and Simon Rainville (Université Laval) led a discussion with participants on the importance of the convergence of research expertise as a means of solving complex problems, stimulating innovation and discovery, and providing sustainable solutions for our societies.

INNOVATIVE LEARNING EXPERIENCE

The Neige experiential project—an initiative of the SMAART CREATE and Sentinel North programs—allowed students to develop, with the help of mentors, optical instrumentation to continuously measure the irradiance profiles of two snowpacks (with and without shrubs) over an entire winter.

« The Neige experiential project was an enriching experience, mainly because it involved creating an instrumentation project, from start to finish, in a short amount of time. The mentors' openness and the teamwork that took place allowed original ideas to come to life, which made the project motivating and interesting.

- Félix Lévesque-Desrosiers, Ph.D. student in physics



Sentinel North community

Over the past year, 14 new interdisciplinary research teams joined the program as a result of Sentinel North's \$9.5M major call for proposals. The partnership research chairs program also led to the creation of three new chairs. These additions brought new collaborations with partners from northern organizations and communities, federal and provincial departments, and the private sector. Young researchers are playing increasingly important leadership roles in our research teams, allowing the program to count on a vast network of expertise and a new generation of scientists to carry on its mission.



In the fall 2020 excellence scholarship and fellowship competition, 13 students and postdoctoral fellows from 9 disciplines were selected for the quality of their applications and the innovative and multidisciplinary potential of their research projects.

WORKING WITH NORTHERN COMMUNITIES DESPITE THE PANDEMIC

The Sentinel North Research Chair on the Relations with Inuit Societies introduced Grade 11 students at the Iguarsivik School in Puvirnituk, Nunavik, to social science research methods through partly face-to-face workshops. The project, aimed to better understand family ties, stimulated synergies between researchers and the community, and allowed the Chair to better understand the evolution of family ties.

The Sentinel North Partnership Research Chair in Ecosystem Approaches to Health (Littoral Chair) [created a video](#) to initiate a dialogue on a new project with the community of Quaqtak, as it was unable to meet with them in person due to COVID-19 restrictions.



Photo: Caroline Hervé



NEW TEAMS

Research Chairs

- The gut microbiome-endocannabinoid system as an integrator of extreme environmental influences on bioenergetics: Cristoforo Silvestri (medicine)
- Sleep pharmacometabolism: Natalie Jane Michael (pharmacy)
- Permafrost in Nunavik : Pascale Roy-Léveillé (geography)

Axis 1. Impact of Environmental Change on Northern Ecosystems and Infrastructure

- Deploying light-based sensing technologies to monitor climate active gases in a mutating Arctic: Martin Bernier (physics, physical engineering and optics), Daniel Nadeau (civil water and engineering)
- Development of resilient municipal wastewater treatment infrastructure targeting water reuse in Nunavik: Céline Vaneckhaute (chemical engineering)
- Ecogenomics of mining areas for sustainable Canadian North (GENOSCAN): Véronique Landry (wood and forest sciences), Damase Khasa (wood and forest sciences)
- Last ice microbiomes and Arctic ecosystem health: Alexander Culley (biochemistry, microbiology and bio-informatics), Warwick Vincent (biology)
- Interdisciplinary research to understand changing food-web dynamics and threats to food security in the northern boreal forest: Daniel Fortin (biology), Jérôme Cimon-Morin (wood and forest sciences)
- A network of automated sensors to monitor arctic animals and environmental changes through advanced computational approaches: Pierre Legagneux (biology), Audrey Durand (computer science and software engineering)

Axis 2: Environment-Health Interactions in the North

- Immersive community co-creation to reconcile well-being and energy performance in Ikaluktutiak architecture: Claude Demers (architecture), Marc Hébert (ophthalmology), Jean-François Lalonde (electric engineering)
- Sustainable and resilient country food systems for future generations of Nunavimmiut: Frédéric Maps (biology), Tiff-Annie Kenny (social and preventive medicine)
- Interactions between the northern environment and chronobiotics: Impact on cardiometabolic and neurometabolic health: Alexandre Caron (pharmacy), Andréanne Michaud (nutrition)
- The exposome-microbiota-brain axis under the microscope to tackle environment-health interactions in the North: Paul De Koninck (biochemistry, microbiology and bio-informatics), Pierre Ayotte (social and preventive medicine)
- Biological signatures of stress responses and potentiality of a diet enriched in n-3 fatty acids to promote positive mental health status despite adversity: Caroline Ménard (psychiatry and neuroscience)
- Assessing the potential of local marine foods accessible from the shore to increase food security and sovereignty in Nunavik: Lucie Beaulieu (food sciences), Ladd Johnson (biology)
- Extreme zooming on intestinal permeability and the western-style diet: Flavie Lavoie-Cardinal (psychiatry and neuroscience), Denis Boudreau (chemistry)

Axis 3: Data Analysis, Predictive Modelling and Knowledge Transfer

- Mobilizing and transferring knowledge between northern communities and Sentinel North: Holly Witteman (family and emergency medicine), Jacynthe Roberge (design)



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