CHAPTER 1

Marine Environments and Human Health

Sentinel North

UNIVERSITÉ LAVAL

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In the context of accelerating climate change and socioeconomic development in the Arctic and Subarctic, the Sentinel North research program at Université Laval helps generate the knowledge needed to improve our understanding of the changing northern environment and its impact on humans and their health. The program fosters the convergence of expertise in the engineering, natural, social and health sciences to catalyze scientific discovery and technological innovation in support of sustainable health and development in the North.

This compendium presents a selection of results from the Sentinel North research program, from its beginning in 2017 through to the end of its first phase in 2022. The results are highlights from innovative research projects and original peer-reviewed publications, which have been integrated into five interdisciplinary chapters addressing major northern issues. Notwithstanding the scale and complexity of these issues, each chapter of the compendium aims to provide new insights through the process of integration, and fill fundamental gaps in our knowledge of the changing North.

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Changing Arctic and Subarctic Marine Environments and Implications for Human Health

Introduction

Arctic and Subarctic marine environments are experiencing rapid and significant changes associated with climate warming. As a result of this warming, the extent of the Arctic sea ice in summer—an important indicator of change—has decreased by about 40% and its thickness by 65% since 1979 (Roebeling et al., 2021; Lindsay and Schweiger, 2015). The loss of sea ice has important ramifications for physical, chemical and biological processes, including changes to heat flux, general circulation, stratification, nutrient supply, primary production, and energy dynamics of food webs (Carmack et al. 2015; Kortsch et al., 2015; Castellani, 2022).

Ice-free warmer waters and consequent changes in ocean currents have been shown to drive the northward expansion of boreal species, including phyto- and zooplankton, and fish (Fossheim et al., 2015; Lefort et al., 2020; Møller and Nielsen, 2020; Oziel et al., 2020). The drastic retreat of sea-ice cover has also been linked to a longer phytoplankton growing season and a 30% increase in annual net primary production in open waters over the entire Arctic Ocean (Arrigo et al., 2015).

Autotrophic single-celled algae, which are the major primary producers in marine ecosystems, use solar radiation to synthesize essential biomolecules that are eventually incorporated into new biomass at higher trophic levels. In the Arctic, most of the biomolecules synthetized by ice-algae and phytoplankton, is channelled up the food chain through the herbivorous copepod *Calanus spp.* (Falk-Petersen et al., 2007). These lipid-rich copepods are then preyed upon by Arctic cod, *Boreogadus saida*, the staple of piscivorous seals, as well as by beluga and narwhal whales (Welch et al., 1992). A fraction of this primary production

also sinks to the sea floor and provides energy and essential fatty acids to fuel benthic secondary production (Grebmeier and Barry, 1991). The availability and nutritional quality of essential biomolecules at the base of the food web are thus important determinants of the productivity and health of entire marine ecosystems and can be significantly affected by changes in sea ice and the amount of light entering the upper ocean (Søreide et al., 2010). One of the challenges of understanding the dynamics of ice-associated marine food webs under different sea ice regimes, is our ability to adequately quantify the transmission of solar radiation through sea ice (Veyssière et al., 2022; Katlein et al., 2021; Perron et al., 2021).

Climate-related changes in marine food webs can lead to cascading effects on northern coastal communities that rely on country foods of high nutritional quality (Falardeau et al., 2022). Shellfish, fish, seals and whales are central to Inuit culture and constitute a diet rich in essential compounds with known health benefits (Lemire et al., 2015; Rosol et al., 2016; Rapinski et al., 2018; Hibbeln et al., 2006; Hu et al., 2018). It has been suggested that Arctic char (*Salvelinus alpinus*), a key fish species harvested by Inuit and a source of essential fatty acids, could be affected by the northward expansion of boreal species through novel interactions occurring in both bottom-up (e.g., through prey availability and quality) and top-down (e.g., through competition and predation) interactions (Power et al., 2012; Falardeau et al., 2022). Contaminant dynamics—i.e., the bioavailability, uptake, bioaccumulation, and fate of environmental contaminants—can also be affected by changes in food web dynamics, including through the increase in transient-boreal species (McKinney et al., 2012; Lemire et al., 2015; Alava et al., 2017).

Mercury (Hg), methylmercury (MeHg), persistent organic pollutants (POPs) and emerging contaminants of concern like perfluoroalkyl acids (PFAAs), which are transported to the Arctic through long-range atmospheric and oceanic transport (Burkow and Kallenborn, 2000), can be highly detrimental to human health. For instance, Inuit coastal populations have the highest MeHg exposure globally (Basu et al., 2018), with potential deleterious effects on their respiratory, endocrine and central nervous systems (Foster et al., 2012). An understanding of the effects of climate change on contaminant processes and exposure in Arctic and Subarctic marine ecosystems, and how such contaminants affect services and health in northern coastal communities, is needed to inform new policies and improve health outcomes (Achouba et al., 2019; de Moraes Pontual et al., 2021).

This chapter gathers a selection of research results from the Sentinel North program that contribute to improving our understanding of the impacts of environmental changes on key processes in Arctic and Subarctic marine ecosystems and the implications for the health of northern coastal populations. Combined, these results address interdisciplinary and ecosystem-level research questions that pertain to climate-related changes in primary production and food web dynamics, notably the availability and quality of essentials compounds; the trophic flux of energy through the major biota of Arctic and Subarctic marine ecosystems; and the role of marine country foods in contaminants exposure and human health.

KEYWORDS:

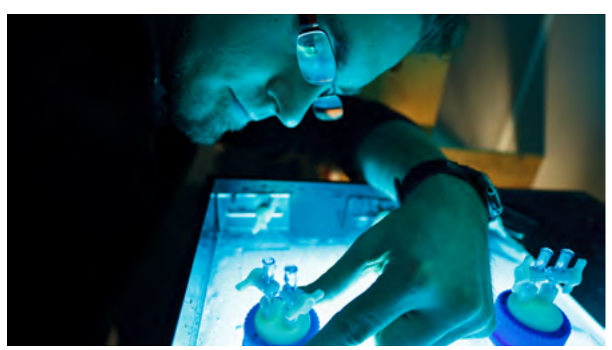
Marine ecosystems, Sea ice, Climate change, Marine food web, Country foods, Oceans, Human health, Energy transfer, Contaminants

1. Shedding Light on Phytoplankton Adaptation to Extreme Conditions

Selected research highlights

Anticipating the Arctic Ocean's responses to shrinking sea-ice and increasing light requires a better understanding of how Arctic phytoplankton adapt to extreme seasonal light regimes.

1.1 Continuous observations over two annual cycles in Baffin Bay, Canada, have shown that net phytoplankton growth can occur in mid-winter and under 100% ice cover. Part of this growth resulted from photosynthesis and highlights the adaptation of Arctic phytoplankton to extreme low-light conditions, which may be key to their survival during the polar night (Randelhoff et al., 2020).

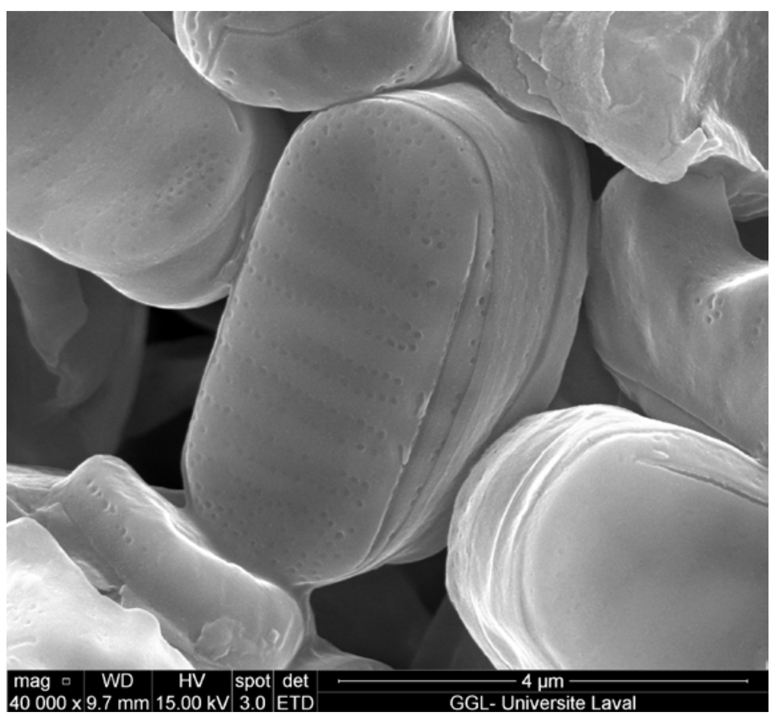


1.2 To improve our understanding of the Arctic Ocean during the polar night, a research team has developed an ultra-sensitive optical sensor in partnership with Biospherical Inc. (Figure 1.2). The sensor, mounted on an autonomous underwater vehicle with enhanced under-ice navigation capabilities, has allowed to make some of the first-ever measurements of light under the ice in the Arctic (Leymarie et al., personal communication).

Figure 1.2
Sensor developed with Biospherical Inc.

1.3 Species-specific photoadaptation strategies, or molecular toolkits, evolved by Arctic diatoms to optimize growth have been shown to be strongly dependent on seasonal light niches (Figure 1.3; Croteau et al., 2022). Unusual photoprotective nonphotochemical quenching and xanthophyll cycle dark patterns could be Arctic diatoms' response to an extreme climate, where light availability is governed by sea-ice cycles, photoperiod, and solar angle (Croteau et al., 2021).

1.4 A first genome-scale model of the species *Fragilariopsis cylindrus*, a pennate sea-ice diatom, was developed to gain insights into the metabolic mechanisms underlying the evolutionary success of diatoms in polar ecosystems. Results demonstrated that the metabolic molecular network in *F. cylindrus* is highly robust in the face of cellular perturbations, a feature that likely helps to maintain cell homeostasis under extreme conditions (Lavoie et al., 2020).



Fragilariopsis cylindrus

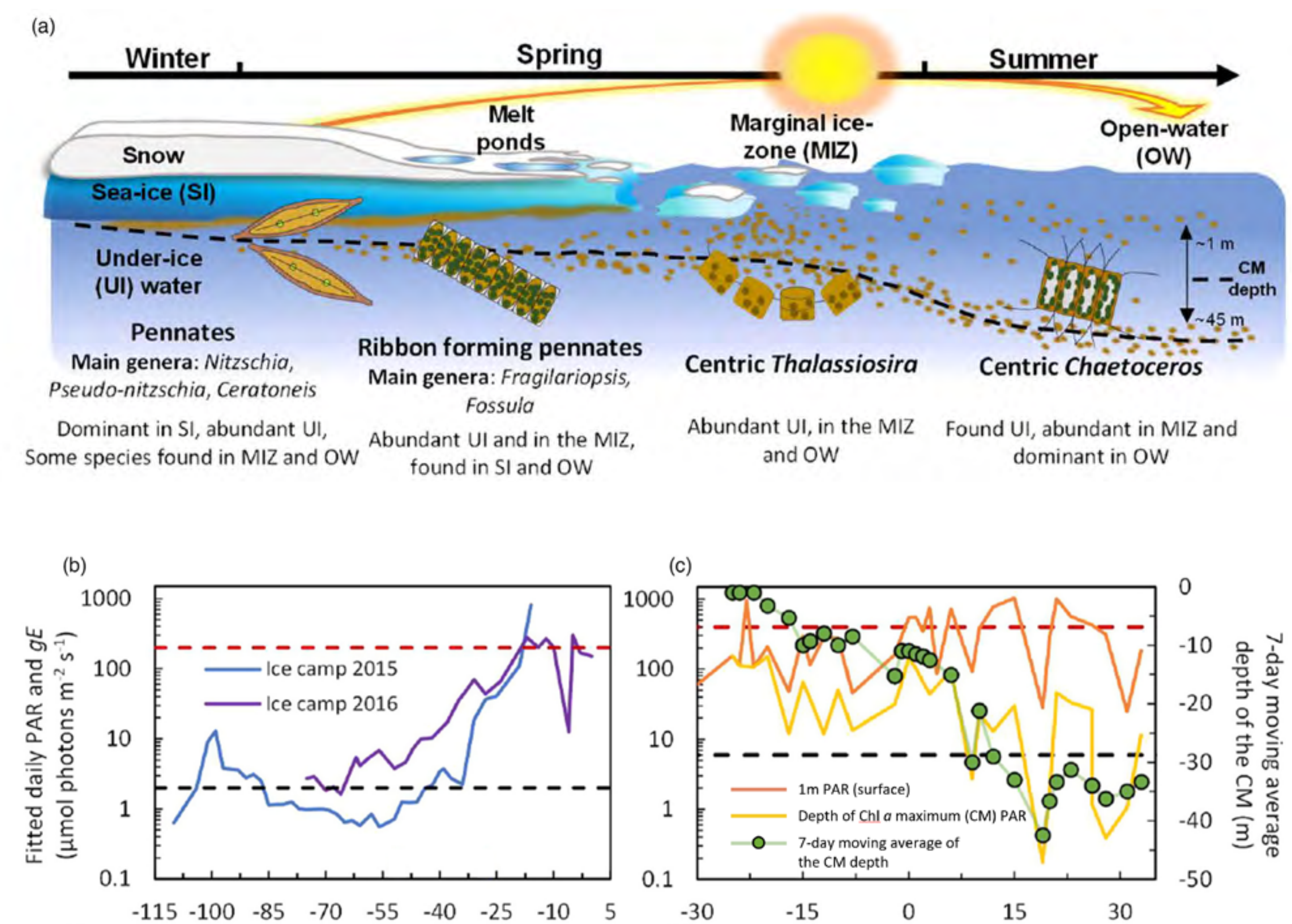


Figure 1.3
Changes in the growing light optima of diatom species favor their succession during the spring bloom in the Arctic. Dotted horizontal lines represent the minimum (black) or maximum (red) growth light intensity (gE) used for the growth of a sympagic (b) or planktonic (c) diatom species. Figure adapted from Croteau et al., 2022, licensed under CC BY 4.0.

“A detailed understanding of how sunlight is reflected and transmitted by the sea ice cover is needed for an accurate representation of critical processes in climate and ecosystem models, such as the ice–albedo feedback.”

Katlein et al., 2021

2. Light Transmission Through Arctic Sea Ice

Selected research highlights

As the Arctic warms, sea ice properties are changing, affecting how sunlight is reflected and transmitted to the under-ice water column with associated impacts on primary production and ecosystem dynamics.

2.1 An innovative optical probe has been designed and tested to measure the inherent optical properties of sea ice in situ (Perron et al., 2021). This probe provides a new, fast, and reliable tool to measure light scattering and better predict ice-associated primary production.

2.2 A new multispectral light sensor chain instrument has been developed to enable direct, autonomous and vertically resolved measurements of light attenuation in sea ice. With frequent deployments over a large area, this low-cost instrument could collect ice-associated light data on much larger spatial and temporal scales. Such data will likely improve radiative transfer schemes in large-scale models (Katlein et al., 2021).

3. Determinants of the Nutritional Quality of Primary Producers

Selected research highlights

The quantity and type of lipids, essential fatty acids and antioxidant carotenoid pigments synthesized by ice algae and phytoplankton are crucial for the health and function of the Arctic marine food web and will be affected, either directly or indirectly, by the rapid transformation of the Arctic environment.

3.1 Changes in the marine physicochemical environment (e.g., seawater temperature, salinity, pH, nutrients and light) along a 3,000 km transect indirectly affected the essential fatty acid, including the omega-3 composition, and carotenoid pigments composition of marine phytoplankton through shifts in species assemblages following spring sea-ice retreat and successive blooms (Marmillot et al., 2020; Amiraux et al., 2022).

3.2 As part of a comparative study of Nunavik marine environments, pH was positively correlated with the production of eicosapentaenoic acid (EPA), one of the key long-chain omega-3 fatty acids, in diatoms. Results obtained through additional covariance analyses suggest a direct and detrimental effect of low pH on diatom cell physiology (Cameron-Bergeron, 2020). Some of the fastest rates of ocean acidification around the world have been observed in the Arctic Ocean and this could have significant effects on the production and transfer of essentials compounds up the food chain.

4. A Changing Marine Environment and Shifts in Species Distribution

Selected research highlights

In the Arctic and Subarctic marine environment, climate warming is triggering poleward shifts in species distributions, which in turn can cause community-wide reorganizations and changes in food web dynamics.

4.1 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 *Emiliania huxleyi*, a phytoplankton tracer of temperate ecosystems (Figure 4.1). This physical and biological "Atlantification"of the Arctic Ocean could affect the entire marine ecosystem by shifting species distributions and impacting energy transfer to higher trophic levels (Oziel et al., 2020).

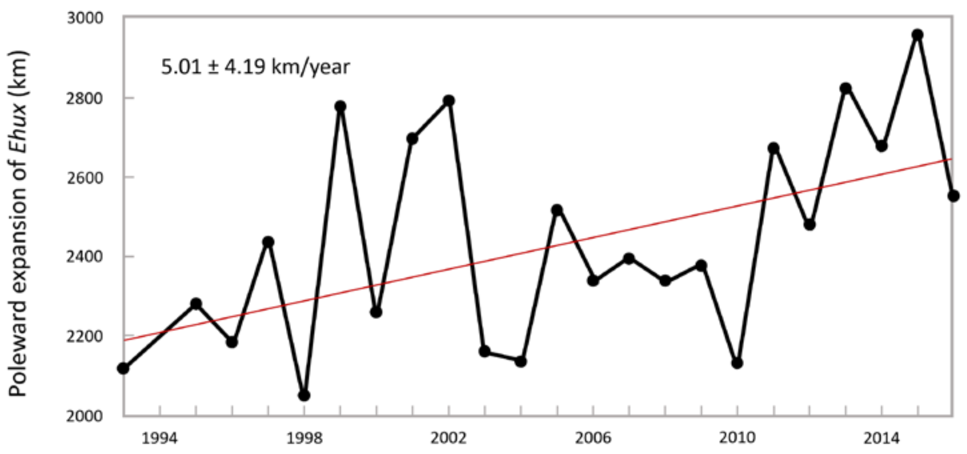


Figure 4.1
Moving north of *Emiliania huxleyi* (Ehux).
Figure taken from Oziel et al., 2020, licensed under CC BY 4.0.

4.2 A morphological trait-based analysis of over 28,000 zooplankton images collected in Baffin Bay, Canada, with an underwater imaging system, revealed that the distribution of copepod traits varies according to water mass properties and spatio-temporal dynamics of ice melt. Large-bodied copepods such as *Calanus hyperboreus* are more abundant in ice-covered Arctic waters whereas smaller species like *Calanus finmarchicus* dominate the open waters advected from the Atlantic (Vilgrain et al., 2021).

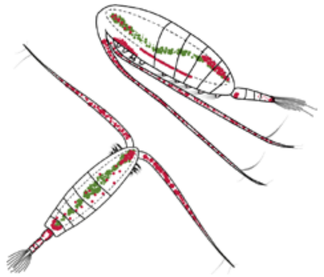


Illustration of Arctic copepods.
© Laure Vilgrain

4.3 Plankton imaging systems are proving key to gain insight into the ecology of secondary producers. In particular, these systems can now be coupled with machine learning techniques to track the distribution of zooplankton using morphological functional trait expression at the individual-level (Orenstein et al., 2022). This novel approach will help shed new light on food web dynamics and carbon cycling in the oceans.

5. Trophic Relationships and Energy Transfer up the Food Web

Selected research highlights

Identifying trophic relationships and the regional and seasonal variability of the dominant pathways by which energy and carbon move through Arctic and Subarctic food webs is essential to determining ecosystem stability, complexity and resilience to climate-induced changes.

5.1 Using fatty-acid markers of diatoms, it was demonstrated that the essential fatty acid content of copepods is influenced primarily by recent feeding on the subsurface chlorophyll maxima (SCM) (Figure 5.1). Long-lived SCMs remain key for zooplankton and the trophic transfer of essential fatty acids in Arctic Ocean food webs. These results also challenge the paradigm that copepods must rely primarily on short-term surface blooms to rapidly store lipids for the following winter (Marmillot, 2023).

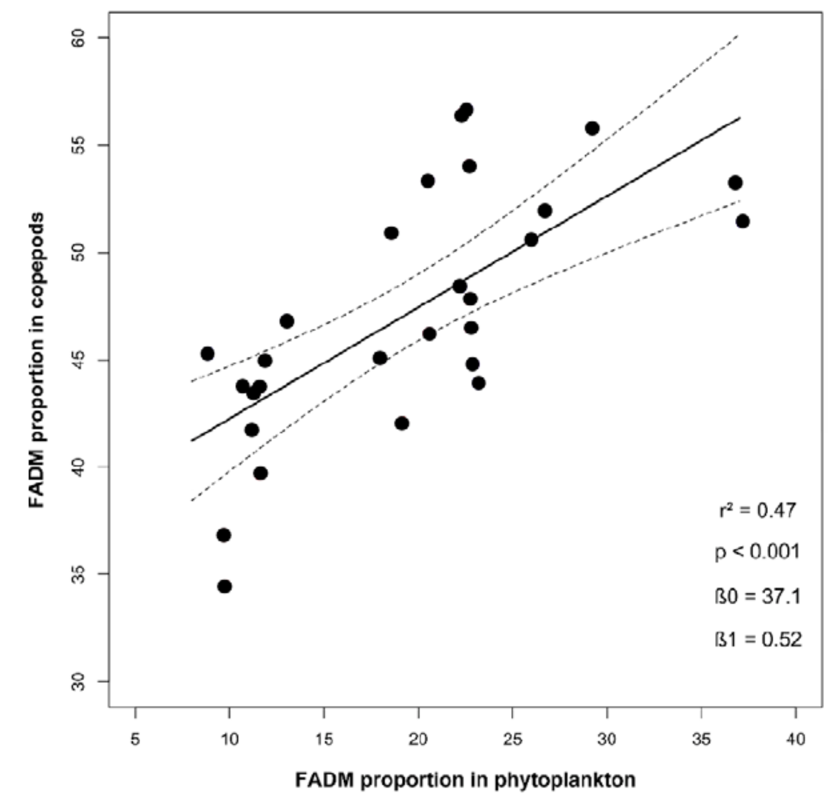


Figure 5.1
Relationship between diatom fatty acid markers (FADM) of phytoplankton and copepods. The dotted lines represent the 95% confidence interval. Figure adapted from Marmillot, 2023, © Vincent Marmillot.

5.2 Strong correlations were observed between the seasonal and annual ice-associated algal production of highly branched isoprenoids and essential polyunsaturated fatty acids (e.g., omega-3) and their presence in Greenland cockle (*Serripes groenlandicus*), an Arctic filter-feeding bivalve (Amiraux et al., 2021). These results underscore the influence of sea-ice lipid production on the quality and reproductive capacity of bivalves and highlight the crucial role that pelagic-benthic coupling plays in nutrient cycling and energy transfer in Arctic food webs.

Serripes groenlandicus

5.3 In Nunavik, benthic organisms with various feeding strategies exhibited differences in nutritional value. Species in higher trophic levels, such as the sea star, generally had higher fatty acid concentrations than those at lower trophic levels (Figure 5.3). They also exhibited levels of selenium comparable to other healthy country foods such as seal and beluga meat and blubber (Van Doorn, 2021).

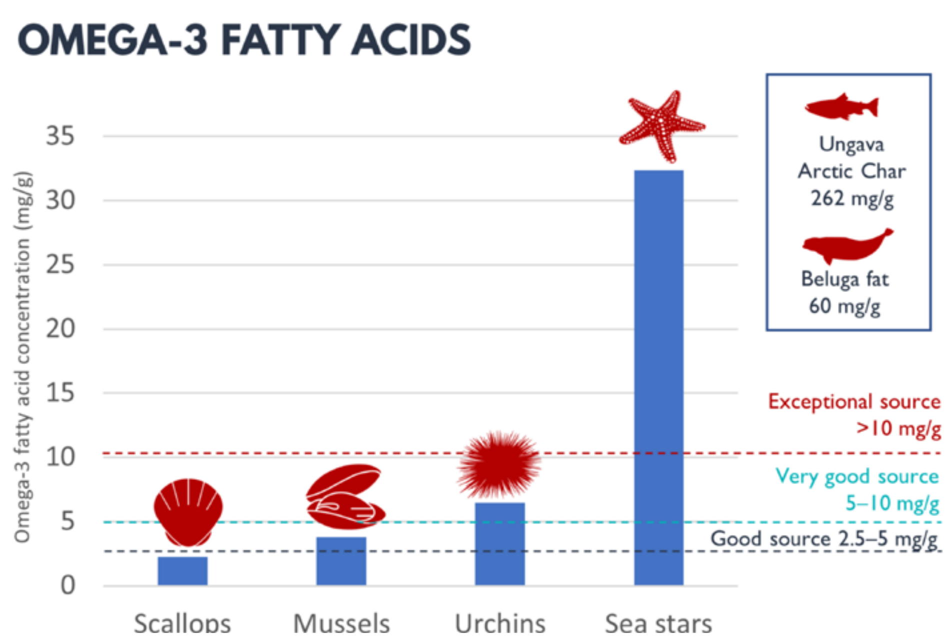


Figure 5.3
Starfish are exceptional sources of omega-3. © Littoral Chair

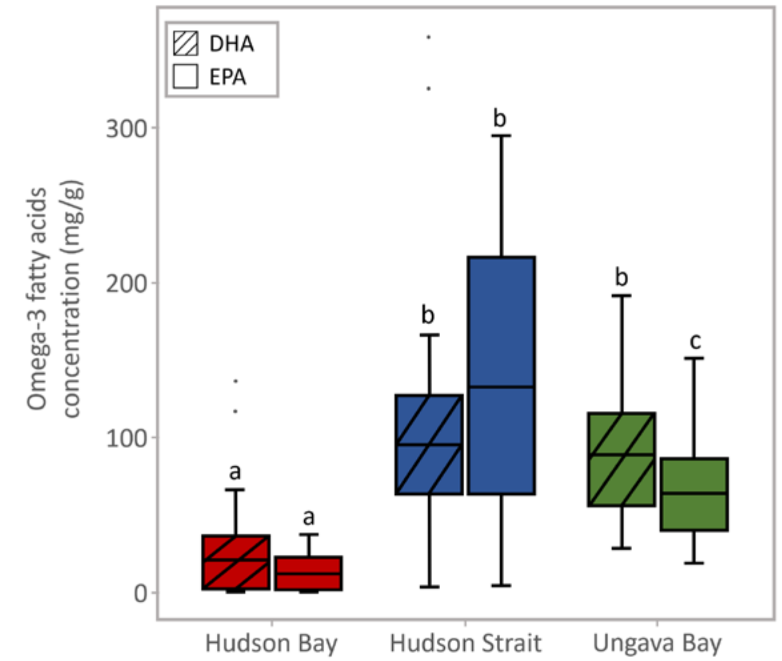


Figure 5.4
Omega-3 content of Arctic char from the three marine regions of Nunavik. The boxplots represent the arithmetic means of the omega-3 concentrations and the standard error of the means. © Sara Bolduc

5.4 The nutritional value of Arctic char (*Salvelinus alpinus*), as measured by concentrations of long-chain polyunsaturated omega-3 in the flesh, varies by region (Figure 5.4) and is linked to differences in diet. Arctic char populations from Hudson Bay and Hudson Strait have a more pelagic diet, while those from Ungava Bay feed on benthic prey. In all three regions of Nunavik, Arctic char have exceptional concentrations of omega-3 (Bolduc, 2021).

Arctic char population genomics

Arctic char is a key species for northern coastal communities, representing a traditional food source rich in essential compounds. The population structure of Arctic char in Nunavik was investigated using genomic methods. The results showed that Arctic char populations are adapted to their environment (temperature, salinity, etc.) and genetically distinct between the three ecological regions of Nunavik: Hudson Bay, Hudson Strait, and Ungava Bay. These results can contribute to regional sustainable management plans for Arctic char fisheries (Dallaire et al., 2021).

6. Environmental Contaminants and Human Health Implications in the North

Selected research highlights

Exposure of northern coastal communities to environmental contaminants through a traditional diet remains a major concern to human health in the Arctic. Monitoring studies provide essential information for local organizations to manage human health risks from exposure to contaminants, while promoting local country foods, which are a source of exceptional nutritional quality and of cultural, social, and economic importance to communities.

6.1 The estimated mean methylmercury (MeHg) intakes based on total country food consumption among pregnant Inuit women in Nunavik revealed significant monthly variations (Figure 6.1) and were two-fold greater than the recommended guidance values for pregnant women. Beluga meat was the primary source of daily MeHg intake for these women, especially during summer and early fall. Understanding seasonal variations in country food consumption is critical to adequately assess MeHg exposure, adopt timely preventive interventions and evaluate the effectiveness of international regulations (de Moraes Pontual et al., 2021).

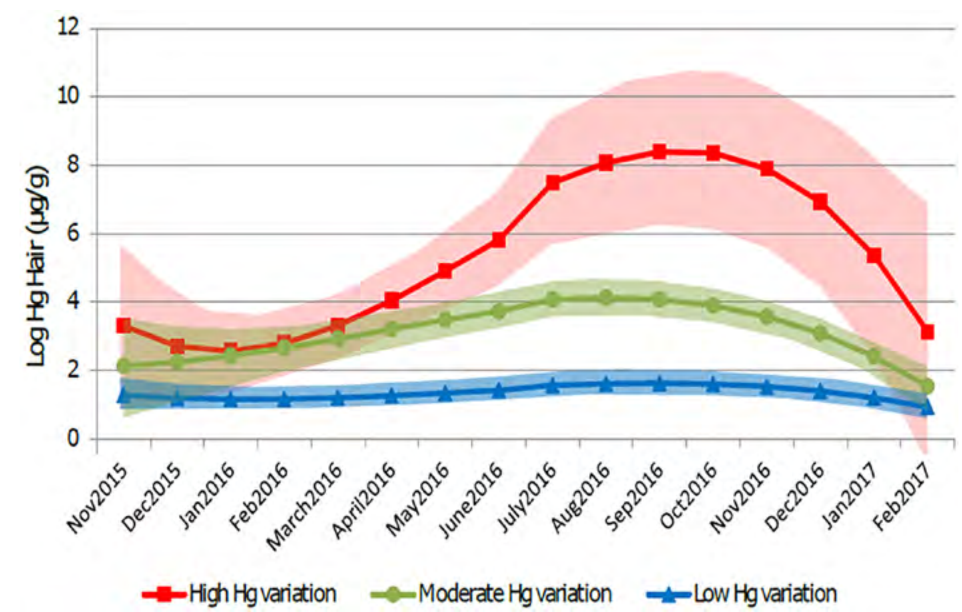


Figure 6.1
Monthly change in concentration of mercury in the hair of three groups of pregnant women in Nunavik. Shaded areas represent the 95% confidence interval. Figure taken from de Moraes Pontual et al., 2021, licensed under CC BY-NC-ND 4.0.

6.2 Selenoneine is the major selenium species in beluga mattaaq. It was also found in high concentrations in the red blood cells of the Inuit in Nunavik (Figure 6.2) and was positively correlated to their consumption of this highly praised country food. One hypothesis under investigation is that selenoneine may protect from methylmecury toxicity by increasing its demethylation in red blood cells (Achouba et al., 2019; Little et al., 2019).

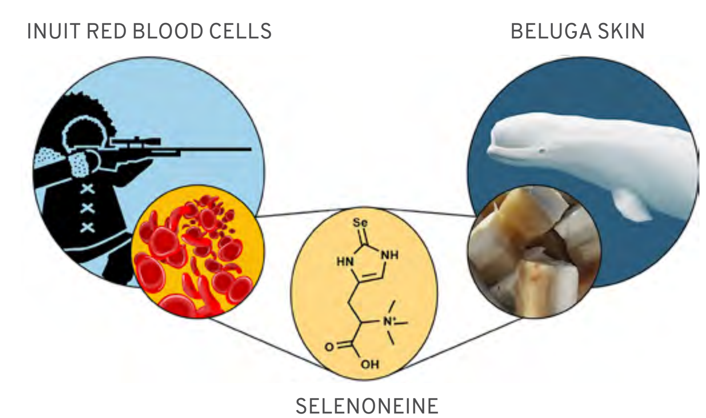


Figure 6.2
Selenoneine is found in high concentrations in Inuit red blood cells and beluga mattaaq. Figure taken from Achouba et al., 2019, licensed under CC BY-NC-ND 4.0.

Towards a portable tool to measure contaminants in country foods

Major steps have been taken to develop a reliable and effective portable tool for detecting mercury in country foods. A new mercury-sensitive fluorophore was synthesized (Picard-Lafond et al., 2020) and its detection properties were investigated. Metal-enhanced fluorescence (MEF) was used in the design of the mercury-sensitive sensor to improve the brightness and photostability of target-responsive fluorophores (Picard-Lafond et al., 2022). MEF has excellent potential for heavy metal detection by fluorescence.

6.3 Long-chain perfluoroalkyl acids (PFAAs) are highly persistent synthetic compounds that can migrate to the poles and accumulate in marine species, particularly those at the top of the food chain. PFAAs exposure concentrations in the Inuit population of Nunavik were shown to be up to seven times higher than those of the general Canadian population (Aker et al., 2021). A host of health effects have been associated with elevated PFAAs exposure in other populations.

6.4 The exposure of pregnant Inuit women in Nunavik to long-chain perfluoroalkyl acids (PFAAs) congeners, such as PFNA, PFDA, and PFUdA, has increased between 2011 and 2017 by as much as 21% in some cases. These exposure levels are among the highest reported in the circumpolar Arctic and elsewhere and indicate that pregnant women in Nunavik are disproportionately exposed to these PFAAs (Figure 6.4) through their bioaccumulation in marine country foods. The implementation of strict regulations in regard to PFAAs is urgently needed to protect traditional country foods (Caron-Beaudoin et al., 2020).

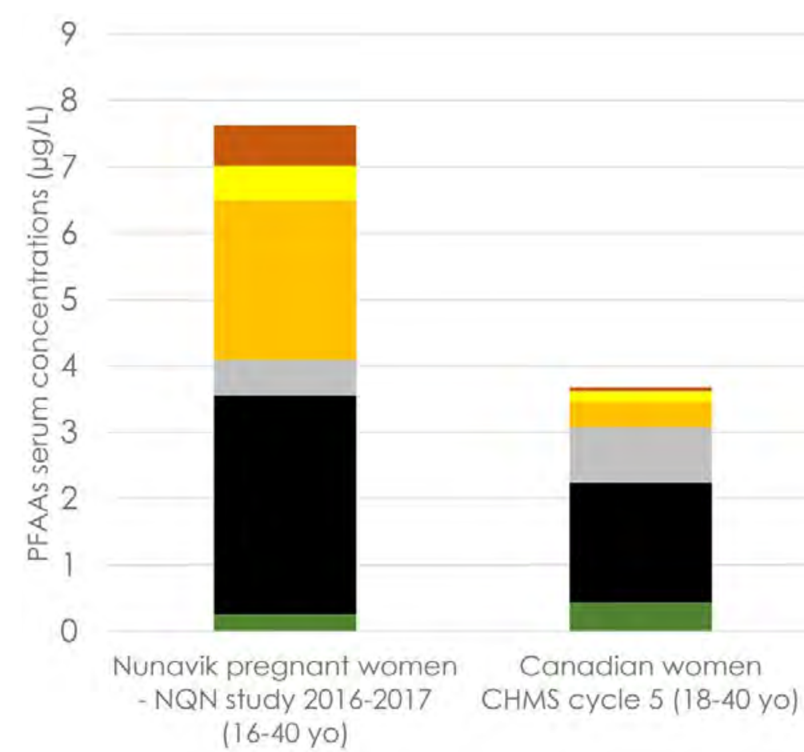


Figure 6.4
The concentration of perfluoroalkyl acids (PFAAs) is higher in pregnant women in Nunavik than in the average Canadian pregnant woman. Figure taken from Caron-Beaudoin et al., 2020, licensed under CC BY-NC-ND 4.0.

From Research Results to Policy Action

Results obtained through a partnership between Sentinel North researchers at Université Laval and Inuit of Nunavik are proving key for Canada's proposal to the Stockholm Convention to regulate per- and polyfluoroalkyl substances (PFAS) and their precursors, also known as 'forever chemicals'. At the 2022 meetings of the Persistent Organic Pollutants Review Committee, Canada's proposal noting the environmental injustice faced by Inuit led the Committee to accept the assessment that these chemicals pose a significant risk to the environment and human health. Long chain-PFAAs therefore moved to the next step in the process, which is to assess the socio-economic impacts of regulatory and management options. Following this step, the Conference of the Parties will decide, in a precautionary manner, whether to ban the use of, or impose strict regulatory measures on, these chemicals.

PFAS are used in many consumer products

Effectively addressing the effects of climate change and environmental contaminants to improve health outcomes requires transdisciplinary perspectives and greater integration of the knowledge production process into policymaking.

Research Projects Cited in this Chapter

The knowledge and technological advances referenced in this chapter were generated by several Sentinel North interdisciplinary research teams. These scientific contributions were gathered from the projects listed below, which involved, in addition to the principal investigators, numerous researchers, graduate students, postdoctoral fellows, research professionals, collaborators, partners from northern organizations and national and international partners from the public and private sectors.

- A better understanding of light-matter interaction: Bridging the gap between micro and macro scales, and developing new devices and approaches for the North

  Principal Investigator: Pierre Marquet (Dept. of Psychiatry and Neurosciences)

- BRIGHT: Bridging global change, Inuit health and the transforming Arctic Ocean

  Principal Investigators: Mélanie Lemire (Dept. of Social and Preventive Medicine), Jean-Éric Tremblay (Dept. of Biology)

- Deciphering host-microbial interactions for cardiometabolic and mental health disorders with novel multimodal light-based sensing tools

  Principal Investigators: Denis Boudreau (Dept. of Chemistry), André Marette (Dept. of Medicine)

- Enabling tools for the monitoring of food quality in the northern environment

  Principal Investigators: Dominic Larivière (Dept. of Chemistry), Jean Ruel (Dept. of Mechanical Engineering)

- The use of diatom microalgae for improving the treatment of the light-driven dysfunctions of the biological clock in Arctic human populations

  Principal Investigator: Johann Lavaud (Dept. of Biology)

- Sentinel North partnership research chair on ecosystemic approaches to health

  Chairholder: Mélanie Lemire (Dept. of Social and Preventive Medicine)

- Sentinel North research chair on the applications and theory of network analysis

  Chairholder: Antoine Allard (Dept. of Physics, Physical Engineering, and Optics)

Some results presented in this chapter are also drawn from research projects conducted by recipients of Sentinel North Excellence scholarship and postdoctoral fellowship awards.

- Génomique de populations de l'omble chevalier au Nunavik et son adaptation locale aux conditions environnementales

  Xavier Dallaire (Master's Scholarship)

- Impact of climate change on the nutritional quality of traditional Inuit foods: *Mytilus edulis* and *Mya truncata* (Bivalvia)

  Rémi Amiraux (Postdoctoral Fellowship)

- In situ optical measurements in sea ice

  Christian Katlein (Postdoctoral Fellowship)

- Modélisation des réseaux moléculaires de l'horloge biologique des diatomées arctiques aux modèles humains

  Michel Lavoie (Postdoctoral Fellowship)

- Network structures of Northern oceanography

  Achim Randelhoff (Postdoctoral Fellowship)

- The association between per and polyfluoroalkyl substances (PFAS) and metabolic outcomes among Nunavimmiut adults

  Amira Aker (Postdoctoral Fellowship)

Research Projects
in this Chapter

Sentinel North has developed partnerships with leading international institutions to conduct innovative and interdisciplinary research projects. The following joint collaborative projects have contributed to the results of this chapter.

- Artificial intelligence application to the identification of functional traits of zooplankton from high-resolution images (ARTIFACTZ)

  Principal Investigators: Éric Debreuve (Université Côte d'Azur), Frédéric Maps (Dept. of Biology)

- Calanus redness index from artificial intelligence applications to image analysis (CARDINAL)

  Principal Investigators: Sünnje Basedow (UiT The Arctic University of Norway), Frédéric Maps (Dept. of Biology)

- Characterization of underneath sea-ice light field variability in the Arctic ocean using underwater and aerial autonomous vehicles

  Principal Investigators: Marcel Babin (Dept. of Biology), Jørgen Berge (UiT The Arctic University of Norway)

- The role of circadian clocks in seasonal synchrony in the Arctic

  Principal Investigators: Johann Lavaud (Dept. of Biology), David Hazlerigg (UiT The Arctic University of Norway)

- Takuvik Joint International Research Unit

  Director: Marcel Babin (Dept. of Biology)
  National Centre for Scientific Research, France
  Associated with the CERC in Remote Sensing of Canada's New Arctic Frontier

Ongoing Sentinel North Research Projects

Several research projects supported by Sentinel North and through joint funding initiatives are ongoing as part of the second phase of the program (2021-2025). These projects, listed hereunder, continue to fill fundamental gaps in our scientific knowledge of the changing North.

- Artificial intelligence application to the identification of functional traits of zooplankton from high-resolution images (ARTIFACTZ)

  Principal Investigators: Éric Debreuve (Université Côte d'Azur), Frédéric Maps (Dept. of Biology)
  Project jointly funded by Sentinel North and Université Côte d'Azur

- CalAct: The impact of light and temperature on Calanus activity patterns in the Arctic

  Principal Investigators: Marcel Babin (Dept. of Biology), Malin Daase (UiT The Arctic University of Norway)
  Project jointly funded by Sentinel North and UiT The Arctic University of Norway

- Calanus redness index from artificial intelligence applications to image analysis (CARDINAL)

  Principal Investigators: Sünnje Basedow (UiT The Arctic University of Norway), Frédéric Maps (Dept. of Biology)
  Project jointly funded by Sentinel North and UiT The Arctic University of Norway

- Characterization of underneath sea-ice light field variability in the Arctic Ocean using underwater and aerial autonomous vehicles

  Principal Investigators: Marcel Babin (Dept. of Biology), Jørgen Berge (UiT The Arctic University of Norway)
  Project jointly funded by Sentinel North and UiT The Arctic University of Norway

- Last ice microbiomes and Arctic ecosystem health

  Principal Investigators: Alexander Culley (Dept. of Biochemistry, Microbiology and Bio-informatics), Warwick Vincent (Dept. of Biology)

- Linking the marine environment and the nutritional quality of shellfish and beluga near Quaqtaq

  Principal Investigators: Mélanie Lemire (Dept. of Social and Preventive Medicine), Jean-Éric Tremblay (Dept. of Biology)
  Project jointly funded by Sentinel North and Institut nordique du Québec

- Nunatsiavut Coastal Interactions Project (NCIP): Climate, Environment and Labrador Inuit subsistence strategies

  Principal Investigator: James Woollett (Dept. of Historical Sciences)
  Project jointly funded by Sentinel North and Institut nordique du Québec

- Screening for emerging Arctic health risks to circumpolar human populations (SEARCH)

  Principal Investigators: Pierre Ayotte (Dept. of Social and Preventive Medicine), Torkjel M. Sandanger (UiT The Arctic University of Norway)
  Project jointly funded by Sentinel North and UiT The Arctic University of Norway

- Sustainable and resilient country food systems for future generations of Nunavimmiut – Promoting food security while adapting to changing northern environments

  Principal Investigators: Frédéric Maps (Dept. of Biology), Tiff-Annie Kenny (Dept. of Social and Preventive Medicine)

- The role of circadian clocks in seasonal synchrony in the Arctic

  Principal Investigators: Johann Lavaud (Dept. of Biology), David Hazlerigg (UiT The Arctic University of Norway)
  Project jointly funded by Sentinel North and UiT The Arctic University of Norway

- TININNIMIUTAIT: Assessing the potential of local marine foods accessible from the shore to increase food security and sovereignty in Nunavik

  Principal Investigators: Lucie Beaulieu (Dept. of Food Sciences), Ladd Johnson (Dept. of Biology)

- UVILUQ: The use of liquid biopsies for monitoring the health of coastal marine ecosystems

  Principal Investigator: Yves St-Pierre (Eau Terre Environnement Research Centre, Institut national de la recherche scientifique)
  Project jointly funded by Sentinel North and Institut nordique du Québec

- Sentinel North partnership research chair on ecosystemic approaches to health

  Chairholder: Mélanie Lemire (Dept. of Social and Preventive Medicine)

- Sentinel North research chair on the applications and theory of network analysis

  Chairholder: Antoine Allard (Dept. of Physics, Physical Engineering, and Optics)

- Takuvik Joint International Research Unit

  Director: Marcel Babin (Dept. of Biology)

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