AMAP / EU-PolarNet

# International Stakeholder Workshops on Research Needs

PART A

Arctic Health and Wellness

PART B

Arctic Ecosystems and Ecosystem Services

PART C

Climate-related Effects on the Arctic Cryosphere and Adaptation Options

PART D

Arctic Biology and Terrestrial Ecosystems

AMAP

EU-PolarNet
connecting science with society

# AMAP / EU-PolarNet
# International Stakeholder Workshops
# on Research Needs

# AMAP / EU-PolarNet
# International Stakeholder Workshops on Research Needs

*Citation:* AMAP / EU-PolarNet, 2020. AMAP / EU-PolarNet International Stakeholder Workshops on Research Needs. Arctic Monitoring and Assessment Programme (AMAP), Tromsø, Norway.

*Published by*
Arctic Monitoring and Assessment Programme (AMAP), Tromsø, Norway (www.amap.no)

*Ordering*
This report is published as an electronic document, available from the AMAP website at www.amap.no

## PRODUCTION

*Production management*
Janet Pawlak (AMAP Secretariat)

*Editing*
Carolyn Symon (carolyn.symon@btinternet.com)

*Layout and technical production*
Burnthebook, United Kingdom (www.burnthebook.co.uk)

*Design and production of computer graphics*
Jane White (studio@burnthebook.co.uk)

*Cover photograph*
Saami man feeds reindeer in Tromsø, northern Norway.
Dmitry Chulov / Shutterstock.com

# Contents

# Preface

There has been a growing interest in polar issues in the political agenda across Europe over the past decade owing to the rapid changes occurring in the polar regions, which are significantly influencing global climate with consequences for global society. As a result, the European Union and its executive body, the European Commission (EC), attribute an increasing importance to science and innovation in the high latitudes. As part of this, in 2015 the EC launched a five-year coordination and support action 'EU-PolarNet – Connecting Science with Society', which is the largest consortium of expertise and infrastructure for polar research, comprising 17 countries represented by 22 of Europe's internationally respected multidisciplinary research institutes. EU-PolarNet has been working in close cooperation with the EC during these five years in shaping Europe's polar research and policy agenda.

The Arctic Monitoring and Assessment Programme (AMAP), as a partner in the Horizon 2020 coordination and support action EU-PolarNet (see box below), is responsible for promoting trans-Atlantic research activities between EU countries and the USA and Canada. One aspect of this is to hold international stakeholder workshops to determine common research needs that can be provided as input to the central EU-PolarNet requirement, namely, to develop an Integrated European Polar Research Programme and implementation plan. An important aspect of EU-PolarNet is 'connecting science with society', under which dialogue and cooperation with relevant Arctic stakeholders ensures their input to the formulation of this research program. To obtain this stakeholder input, AMAP in cooperation with EU-PolarNet conducted four International Stakeholder Workshops on Research Needs on a range of Arctic issues of importance to science and society.

This report compiles the outcome of the four workshops, highlighting key research needs to better understand Arctic ecosystems and human health and wellbeing in the Arctic and the influence of climate change on them.

Nicole Biebow
Project Manager, EU-PolarNet
Alfred-Wegener-Institut,
Helmholtz-Zentrum für Polar- und Meeresforschung,
Bremerhaven, Germany

Janet Pawlak
AMAP Deputy Executive Secretary
AMAP Secretariat
Tromsø, Norway

## EU-PolarNet – Connecting Science with Society

EU-PolarNet is a Horizon2020 Coordination and Support Action with the ambition to connect science with society. Seventeen countries represented by 22 of Europe's internationally respected multi-disciplinary research institutions are building the world's largest consortium of scientific expertise and infrastructure for polar research. The EU-PolarNet consortium aims to develop effective research strands and successful partnerships that will address the urgent need for knowledge about changes in the Polar Regions.

From 2015-2020, EU-PolarNet will develop and deliver a strategic framework and mechanisms to prioritise science, optimise the use of polar infrastructure, and broker new partnerships that will lead to the co-design of polar research projects that deliver tangible benefits for society. By adopting a higher degree of coordination of polar research and operations than has existed previously the consortium engages in closer cooperation with all relevant actors on an international level.

EU-PolarNet will develop an Integrated European Polar Research Programme in a truly transdisciplinary approach building in the challenges and needs raised by stake. And right holders affected by the ongoing changes in the Polar Regions. The Integrated European Polar Research Programme aims at identifying short and long-term scientific needs and optimising the use of co-ordinated Polar infrastructure for multi-platform science missions whilst fostering transdisciplinary collaboration on Polar research.

EU-PolarNet will also create and sustain an ongoing dialogue and co-operation with the European Commission to shape future research, exchange key information and provide evidence based advise to decision making.

*Cloudberries,* Rubus chamaemorus *by Randi Hausken*

PART A

# AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs for Arctic Health and Wellness

Fairbanks, Alaska, 12 March 2016

## Contents

# Executive Summary

A new reality under climate change requires a new community health research agenda that will respond in a much more integrated way to the needs and priorities of the Circumpolar North, led by Indigenous peoples and working in strong partnership with local, regional, national, and international stakeholders. Health sovereignty – or the ways in which communities are able to achieve optimal health and wellness, through culturally, environmentally, politically, and historically relevant pathways – will be an essential framework for assessing and evaluating both climate-change-sensitive health impacts and health mitigation and adaptation responses, and for formulating interdisciplinary and multi-sectoral circumpolar research priorities.

Cooperation among Arctic countries should be strengthened and international networks should be further developed on health issues. Priority issues include mental health; vectorborne infections; modeling ecological changes such as range shifts, temperature changes, and changes in precipitation; increased and better national monitoring; and communication of the findings to national and local health authorities.

To evaluate whether general public health status is threatened by societal and climate change, more general data on individuals needs to be collected over a period of time in a way similar to the contaminant cohort studies conducted in the Arctic Monitoring and Assessment Programme (AMAP) human health work. This similarity gives the possibility for conducting joint projects with prospective studies in the future, with information collected to analyze associations between contaminants and health effects as well as for analyses of associations between lifestyle factors and health status. Investigations of the relationship between contaminant exposure and health effects can best be achieved by well-designed and implemented cohort studies, representative for the population and large enough to be able to draw conclusions. Representative tissue samples should also be collected for contemporary and future analysis. Mother-child cohort studies with long-term follow-up are needed to elucidate the impact of contaminant exposure during fetal life and the risk of disease later in life. The establishment of joint cohorts in the various regions of the Arctic will provide a number of advantages.

Proposals include development of a circumpolar biomonitoring strategy that covers both humans and key wildlife species to provide data on exposure to contaminants, zoonotic pathogens, and harmful algal bloom toxins. This should include standardizing zoonotic antibody testing for a range of infections found with a circumpolar distribution and the possibility of establishing a network of rural hunters willing to use filter papers to take blood samples from harvested animals for analysis of contaminants and pathogens. This would enable the tracking of trends in zoonotic infection and contaminant exposure and the movement of pathogen species among regions. Research on the most effective method of establishing local capacity for hunters to use filter paper blood sampling of subsistence species should be considered by all circumpolar countries.

Research should be considered on the impact of climate change on the mental health of people in the North and the Arctic as they are most affected by the environmental changes that impact culturally critical and nutritionally important traditional subsistence activities. In identifying research needs for Arctic health and wellness, questions should be considered concerning the definition of resilience in a culturally and ecologically specific context, and ways to conduct interventions that promote and support resilience and wellbeing, as defined by the coping, adaptive and transformative capacities of social-ecological systems and communities at the local level.

There is a need for an interdisciplinary, holistic approach to research and program development on mental health and wellness that is community-driven and in line with community-level factors shown to be protective and culturally important. There is also a need to determine important steps for knowledge generation and dissemination to improve the health of Arctic people. This new approach should be community-driven and evaluated. Community members are best able to prevent suicide and promote wellness. However, scientific research is useful to strengthen and guide local efforts. Arctic health research efforts should partner with tribes, organizations and other community structures (including sharing funding with them) and build onto local systems. Research outcomes should provide resources, insights or tools to communities and organizations so that they can most effectively work toward health equity.

Studies should be solution-focused instead of problem-focused and there should be rigorous evaluation of the results. This involves reframing health research from a problems-and-deficits model to one seeking to understand what protects community health. This approach necessarily draws upon traditional knowledge, culture, spirituality, language and local resources to define community-based solutions to health challenges. Health care solutions to problems in the North will require practices and solutions designed by people of the North in collaboration with external expertise.

Research partnerships in the North should include local and Indigenous people. PhD opportunities should be made more accessible in the North as communities can do much more regarding research in partnership with universities and other research organizations. Such research should include the impact of government policies that may have more impact on an Indigenous community than climate change.

Building local capacity and strengths is important and consideration should be given to how to support more capacity building for researchers and health professionals as well as to connect research with education in the North.

# A1 Background

Rapidly occurring changes in the Arctic, including economic development, resource exploitation, socio-cultural alterations, and the various impacts of climate and environmental changes, are having an influence on the physical and mental health and wellness of Arctic residents, particularly Indigenous peoples around the Circumpolar North. Research is needed to be able to understand these impacts on health and to assist in the development of means to ameliorate such impacts. Arctic residents, especially Indigenous people, and other relevant stakeholders in the Arctic need to be involved in the identification of the types and topics of research that are needed, the methods used, and the conduct and approaches of the work, to ensure that the results will be usable, locally and culturally appropriate, and capable of being implemented.

The Arctic Monitoring and Assessment Programme (AMAP), as a partner in the Horizon 2020 coordination and support action EU-PolarNet, is responsible for promoting trans-Atlantic research activities between EU countries and the USA and Canada and, as one aspect of this, to hold stakeholder workshops to determine common research needs that can be provided as input to the central EU-PolarNet requirement, namely, to develop an Integrated European Polar Research Programme together with an implementation plan. An important aspect of EU-PolarNet is 'connecting science with society', under which dialogue and cooperation with relevant Arctic stakeholders will ensure their input to the formulation of this research program. AMAP organized this first of four annual stakeholder workshops to identify and formulate key Arctic research needs over the next five years. The central theme of this workshop is research needs associated with the health and wellness of Arctic residents.

The format of the workshop, after the introductory presentations setting the background and aims of the workshop, comprised presentations by several experts from around the Circumpolar North on a theme followed by discussion by the participants of the ideas presented and identification of research needs requiring further work. The workshop, as a group, then worked to prioritize key themes and approaches.

For a quarter of a century, AMAP has coordinated contaminant-related studies of health in the Arctic; this work has recently expanded to include the combined effects of other stressors, particularly climate change, on health. The AMAP Human Health Assessment Group also cooperates with the Human Health Expert Group under the Arctic Council Sustainable Development Working Group, which has a particular focus on the mental health of Arctic residents. Experts from these groups have assisted in the preparations for this workshop. Representatives of Arctic Council Permanent Participants, which are organizations that represent a large percentage of the Indigenous peoples in the Arctic, are also important to this process. A map of the share of Indigenous populations in the Circumpolar North is shown in Figure A1.

# A2 Introduction

Representatives of the two co-sponsors of the workshop, AMAP and EU-PolarNet, provided the overall background for the workshop.

Lars-Otto Reiersen, AMAP Executive Secretary, briefly described the origins of AMAP 25 years ago and the structure of the Arctic Council, established five years later, which provides for the active involvement of and engagement with indigenous communities in the Arctic. Six international Indigenous peoples' organizations are designated as Permanent Participants to the Arctic Council and its working groups. They provide for contributions to the work of the Arctic Council relevant to most of the roughly one million Indigenous people in the Arctic (out of a total population of about 4 million).

As one of the six working groups under the Arctic Council, AMAP has coordinated monitoring programs for contaminants and their effects among the eight Arctic countries since its inception, with monitoring data compiled at thematic data centers. AMAP has also conducted numerous assessments on persistent organic pollutants, mercury and radionuclides in the Arctic environment and, more recently, on climate change and the cryosphere. Human health has been an important topic, particularly the exposure of Arctic residents, and especially Indigenous people, to environmental contaminants and concentrations of contaminants in wildlife species consumed. This includes coordination of a biomonitoring program on contaminants in the blood of Arctic residents to follow temporal trends in exposure levels (see Figure A2 for a map showing the communities monitored). For a broader understanding of contaminant trends and effects, most Arctic countries have established cohort studies of specific segments of the population, particularly mothers and their children. Results of these studies are reported in AMAP human health assessments, of which the fourth report has just been published (AMAP, 2015). Each major assessment report is accompanied by a summary report for policymakers containing policy-relevant science-based key findings. Results are also contributed to relevant UN agencies, including the United Nations Environment Programme (UNEP) and the Intergovernmental Panel on Climate Change (IPCC), for their use.

Dr. Nicole Biebow, Project Manager of the EU coordination and support action EU-PolarNet, presented a brief overview of this activity. She noted that polar issues have been rising up the political agenda across Europe over the past decade owing to the rapid changes occurring in the polar regions, which are significantly influencing global climate with consequences for global society. As a result, the European Union and its executive body, the European Commission (EC), attribute increasing importance to science and innovation in the high latitudes for a variety of reasons. As part of this, the EC launched a five-year coordination and support action 'EU-PolarNet – Connecting Science with Society' – which is the largest consortium of expertise and infrastructure for polar research, comprising 17 countries represented by 22 of Europe's internationally respected multidisciplinary research institutes. EU-PolarNet will work in close cooperation with the EC in the next five years in shaping Europe's polar research and policy agenda.

EU-PolarNet is establishing an ongoing dialogue between policymakers, business and industry leaders, local communities and scientists to increase mutual understanding and identify new ways of working that will deliver economic and societal benefits. The results of this dialogue will be brought together in a plan for an Integrated European Research Programme for the Arctic and the Antarctic. This will be co-designed with all relevant stakeholders and coordinated with the activities

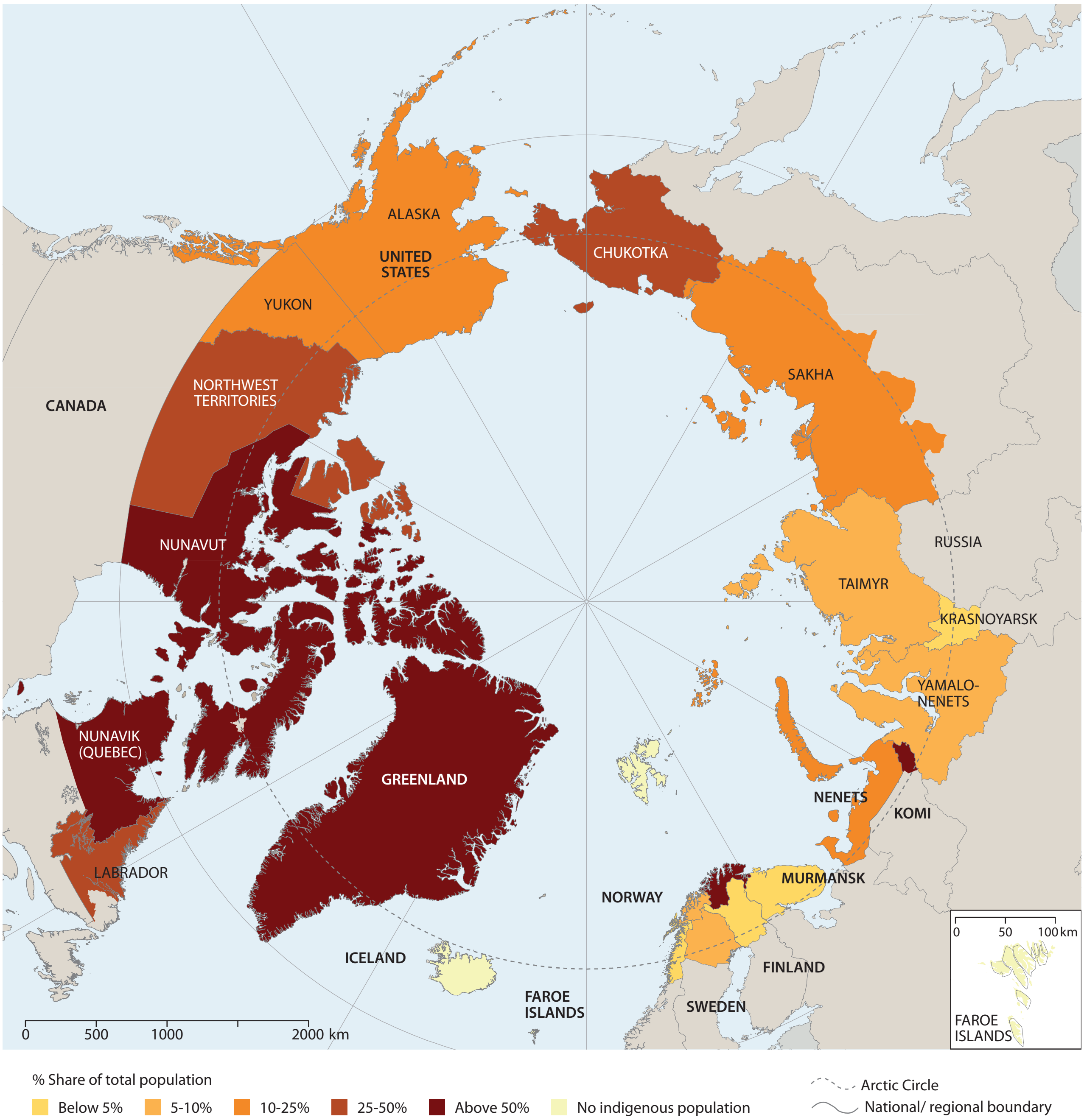


Figure A1 Indigenous population in the Arctic regions as a percentage of the total population in the period 2001 to 2006. Source: Nordregio.

of many other polar research nations beyond Europe, with which consortium partners already have productive links. This especially includes cooperation with Canada and the United States, particularly under the Trans-Atlantic Research Alliance. As part of this activity, EU-PolarNet is preparing a report on prioritized objectives for polar research. It is also designing a resource-oriented European infrastructure access and usage plan to support the integrated research program. Additionally, EU-PolarNet is cooperating closely with the European Commission by providing support and advice on all issues related to the polar regions. An affiliated partner, the European Polar Board, is supporting the work and will ensure that the legacy of EU-PolarNet will be sustained.

The workshop organizer and meeting rapporteur, Janet Pawlak, AMAP Deputy Executive Secretary, emphasized the importance of this workshop as one of the stakeholder contributions to the further development of prioritized objectives for Arctic research and ultimately the Integrated European Research Programme for the Arctic. As health is only one of many research topics for the Arctic, it is vital that this workshop identify the most important research needs to support health and wellness in Arctic communities and people. These research needs will be included in the report she will prepare based on the presentations and discussions at the workshop for submission to EU-PolarNet as a stakeholder contribution on health issues in the Arctic.

The workshop facilitator, Dr. Rhonda Johnson, Professor of Public Health at the University of Alaska Anchorage, welcomed the participants and noted that all are stakeholders in relation to the health and wellness of residents of the Arctic and northern communities. She encouraged participants to make comments and raise issues to provide diverse stakeholder perspectives on this very broad topic.

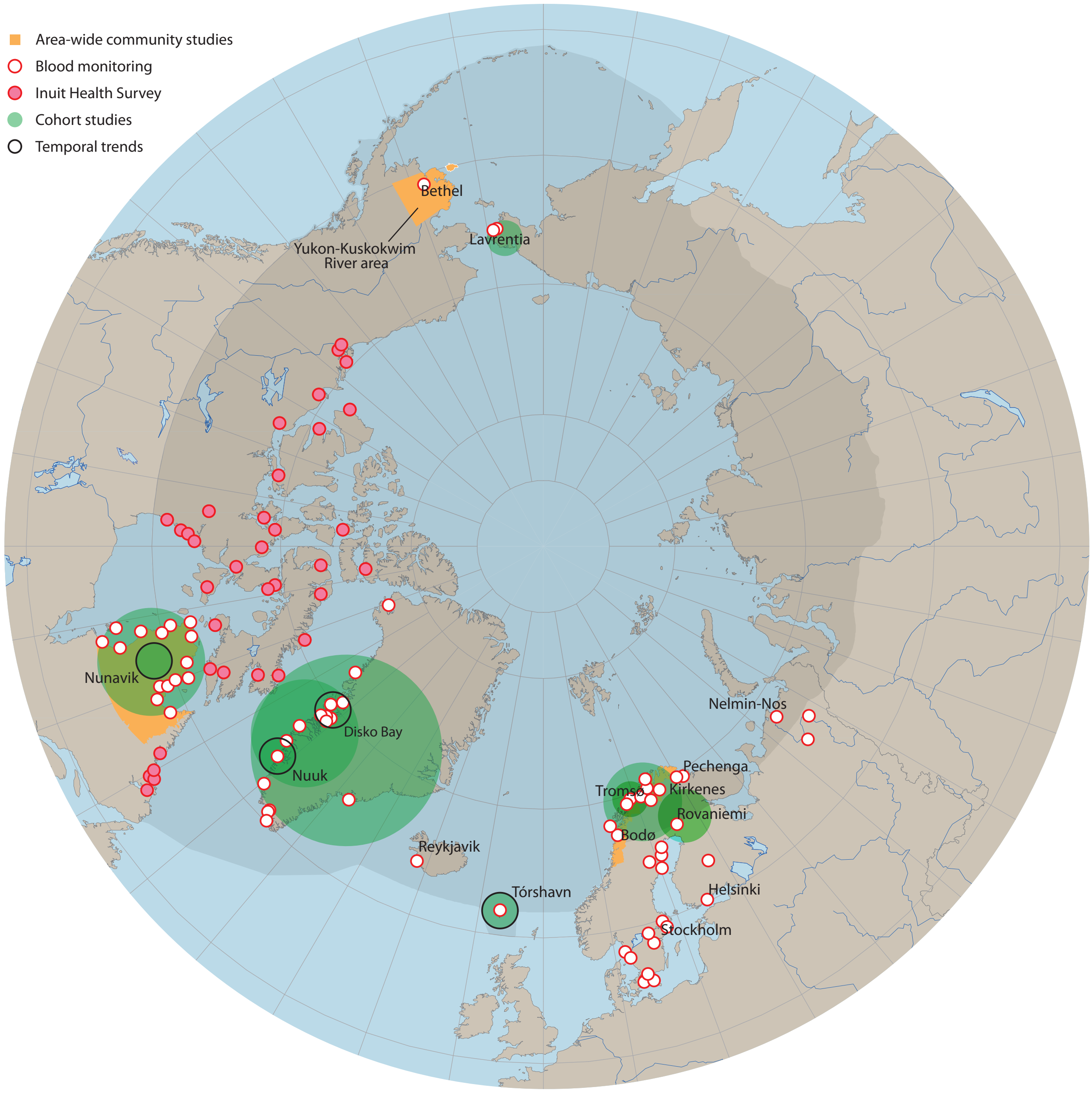


Figure A2 Communities for which biomonitoring data on contaminants are available, some cover many years of trend monitoring. Source: AMAP (2015).

# A3 Climate change and health in the circumpolar North

## A3.1 Overall perspectives on climate change and health in the circumpolar North

Dr. Ashlee Cunsolo, Canada Research Chair in Determinants of Healthy Communities and Associate Professor at Cape Breton University, stated that climate change and health should be the main priority for research in the Arctic. A 2009 Lancet commission identified climate change as the 'biggest public health threat of the 21st century'. Climate change will affect physical and mental health and the consequences will be wide-ranging and far-reaching.

The circumpolar North is experiencing some of the most rapid changes in climate and environment in the world, with disruptions to sea-ice regimes, including later formation and earlier break-up and decline in sea-ice extent; increased surface air temperature; thawing permafrost; changes in weather and snow patterns; and disruptions to wildlife and vegetation. These changes are currently disrupting the livelihoods and cultural practices of many Northern peoples, particularly Indigenous populations, leading to a range of climate-change-related health impacts: increased death and injury from unstable ice conditions and unpredictable weather; increased risk, frequency, and distribution of foodborne, waterborne, and vectorborne disease; increased heat stress and sunburn; increased respiratory challenges from new allergens, dust, and forest fires; magnification of health impacts from anthropogenic environmental contaminants; displacement and forced relocation from sea-level rise and coastal erosion; and widespread mental health impacts from both direct and indirect impacts.

These climate-change impacts affect the land on which Indigenous people live. An overview of determinants of wellbeing in Inuit communities in Canada showed that land is the basic need for wellness; land underpins all understanding of health and wellness in these communities, serving as the platform on which are built friendships, community activities, cultural skills, traditional knowledge and many other aspects that contribute to wellbeing. The entire system of wellbeing of these communities is premised on the ability to travel safely, reliably, and regularly on the land to hunt, trap, fish, pick berries, travel and a multitude of other activities that have been part of their culture and livelihood for centuries – aspects that are now being threatened or destroyed by changes in the land, weather patterns, and the ice regime. This affects food security owing to changes in the wildlife, berries and other traditional food sources and has a large impact on mental health, manifested by strong emotional responses, loss of land-based activities, changing cultural identities, potential increases in addictions, interpersonal violence and suicide rates, and the amplification of other physical and mental health stressors.

Climate-change-sensitive health impacts are a pressing priority across the circumpolar North, and how communities, governments, researchers, and policymakers act and respond will be defining moments moving forward. The prospect of a way of life being taken away owing to major changes in the environment arising from circumstances beyond the control of a community contributes direct and indirect stressors on the people. Community health needs to be supported by enhancing preparedness for a new reality under climate change. This requires a new research agenda that will respond in a much more integrated way to the needs and priorities of the Circumpolar North, led by Indigenous peoples and working in strong partnership with local, regional, national, and international stakeholders. In particular, health sovereignty – or the ways in which communities are able to achieve optimal health and wellness, through culturally, environmentally, politically, and historically relevant pathways – will be an essential framework for assessing and evaluating both climate-change-sensitive health impacts and health mitigation and adaptation responses, and for formulating interdisciplinary and multi-sectoral circumpolar research priorities.

### A3.2 Local perspective: Labrador case studies and research opportunities to understand the compounding impact, of Climate Change and Government Policy on Arctic Health and Wellness

Jamie Snook, the Executive Director for the Torngat Wildlife, Plants and Fisheries Secretariat and the Mayor of Happy Valley-Goose Bay, stated that the health impacts of climate change are a priority across the circumpolar North and recently featured in documentary films such as *Lament for the Land* directed and produced by Dr. Cunsolo and the five communities of Nunatsiavut (www.lamentfortheland.ca/film). Many of the mental health impacts are amplified by government policies that make traditional Inuit ways of life an increasing challenge. The Labrador Inuit Land Claim Agreement recently celebrated its tenth anniversary. After ten years of fisheries and wildlife co-management, there are case studies that represent opportunities to research and explore how changes to policy could perhaps positively impact the health and wellness of Labrador Inuit, and help to counteract climate change impacts.

Land, plants, fish and wildlife are paramount to health and wellness. In Nunatsiavut there are five communities, ranging from 300 people to 1200 people per community and representing 4% of Inuit in Canada. Food security is very important to these communities. Arctic char is a main staple food; this fish species is being impacted by climate change, and a 40-year scientific program to study and maintain the stock is at risk of being closed. Atlantic salmon is another important staple; this species is managed by the North Atlantic Salmon Commission, which looks critically on maintaining a minimum quota for each Inuit household. The current quota is six fish per household. Lake Melville is an important source of ringed seal, salmon, char and smelts for these communities, as well as being considered an ecologically and biologically significant area by the Department of Fisheries and Oceans Canada. However, a hydroelectric dam is under construction that will increase the concentration of methylmercury, the most toxic form of mercury, by up to 200%. Other important food resources affected by government policies include (a) northern shrimp, for which the Inuit quota has been seriously limited so small communities cannot benefit from these fisheries; (b) halibut, for which Inuit receive 3.3% of the total quota; (c) caribou, which is subject to a government ban on hunting resulting in large emotional and mental health effects on people in the region; and (d) polar bear, for which hunting is also limited. Climate change is an important factor in the limitation on hunting polar bears as it is a major stress on polar bears and is probably also affecting the caribou population.

Climate change is also affecting the types of species in the fishing areas of these communities, with dwindling numbers of cold-water shellfish, but increasing numbers of groundfish entering the warming ocean. Communities need to prepare for these changes.

Research is needed on the impact of government policies on the food security and health of Indigenous people in the Arctic.

### A3.3 Contaminants in Arctic food species: health effects issues

Dr. Pál Weihe, Chief Physician, Department of Occupational Medicine and Public Health in the Faroese Hospital System, explained that prenatal exposure to methylmercury has been associated with effects on the developing brain of children. Effects associated with mercury exposure have been documented in humans at successively lower exposures and it is clear that the developing brain is the most vulnerable organ system. Even minor damage is permanent and, by lowering a child's IQ, affects educational ability and income later in life. Although generally the exposure to mercury is decreasing, in parts of the Arctic exposure levels of methylmercury are still at a level where effects can be expected (Figure A3) and monitoring the effects is needed.

Some studies have suggested potential effects of polychlorinated biphenyls (PCBs) and perfluorinated compounds (PFCs) on the immune system of children in the Arctic; however, further studies are needed to improve understanding and quantify this relationship. Studies have also suggested that exposures to certain persistent organic pollutants (POPs) are associated

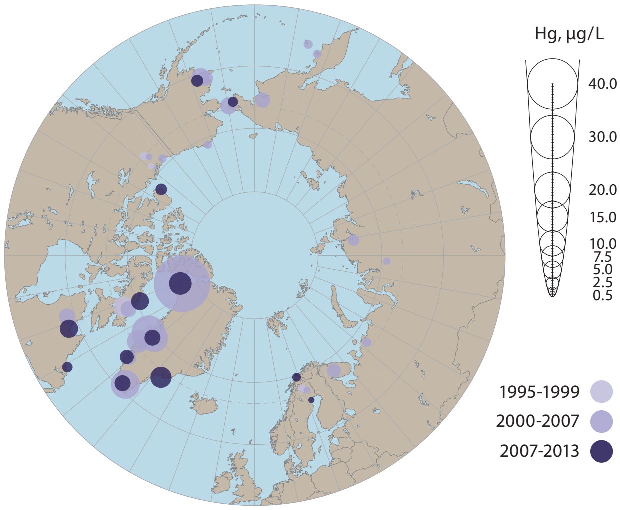


Figure A3 Circumpolar concentrations of mercury in blood of mothers, pregnant women and women of child-bearing age during different periods. Source: AMAP (2015).

with an increased risk of developing Type 2 diabetes in Arctic populations. Despite recent studies, current knowledge remains limited. Genetic predisposition to mercury neurotoxicity has also been suggested; however, studies in the Arctic are limited and are needed to explore this possibility.

Follow-up studies on mother-child cohorts are needed to elucidate the impact of contaminant exposure during fetal life and the risk of disease later in life.

Thus, as there will be a need in the coming several decades for monitoring of contaminant levels in Arctic populations as well as a need for investigating the relationship between contaminant exposure and health effects, this can best be achieved by well-designed and implemented cohort studies. Characteristics of such investigations are that they are representative for the population or populations under investigation and are large enough to be able to draw conclusions even for rare or unusual conditions. Furthermore, representative tissue samples should be collected in adequate quantities for contemporary analysis as well as when the participants in the cohort become older. However, such investigations are very expensive.

In order to evaluate whether the general public health status is threatened by societal changes and climate change, there is also a need to collect more general data on individuals over a period of time, for example, 10 to 20 years. This type of study is similar to the contaminant cohort studies conducted in the AMAP human health work. This similarity gives the possibility for conducting joint projects with prospective studies in the future, such that information is collected in relation to the analysis of associations between contaminants and health effects as well as information of relevance for analyses of associations between lifestyle factors, among others, and health status.

The establishment of joint cohorts in the various regions of the Arctic will have a number of advantages, among them: they will be considerably cheaper to establish; they will relieve the local societies of repeat investigations and thus also increase the proportion of the population that participates in the investigation; they will establish a bridge between the various research initiatives arising from the problem of contaminants and from the problem of sustainable development.

## A3.4 Combined effects of climate change, contaminants and zoonotic diseases

Dr. Birgitta Evengård, Professor, Division of Infectious Diseases, Department of Clinical Microbiology, Umeå University in Sweden, noted that there are many challenges and opportunities in the Arctic. Arctic ecosystems have many things in common: they are vast and sparsely inhabited, they are facing rapid climate change and they are subjected to increased tourism and trade with the rest of the world. At the same time, they consist of cold-adapted species, making them particularly vulnerable to pressures like climate change and invasion by all types of organisms, including plants, animals and pathogens causing human diseases. Humans are part of ecosystems; ecosystems affect and are affected by societies and human health is related to both. With climate change, new species are moving north, bringing with them zoonotic diseases; thus, the health of animals cannot be separated from the health of humans. One example is that willow trees are moving north, bringing beavers and some diseases. Indigenous people may be more vulnerable to such new diseases, possibly because of their genetics.

For the Saami in northern Norway, Sweden and Finland, reindeer herding is very important. With climate change, reindeer are affected by thin ice and a lack of food, and they are becoming more susceptible to disease. The more than two million semi-domesticated reindeer in the Arctic are at risk from the midge-borne virus blue tongue and the mosquito-borne West-Nile fever. Uncertainty caused by these changes in conditions is causing stress in Saami communities in these and other areas where the traditional foods, lifestyle and culture are being affected by climate-related changes.

Another example is that ticks are moving northwards with the warmer weather bringing with them a number of micro-organisms such as the virus causing tick-borne encephalitis and the spirochetes causing borreliosis in humans. There are a number of potentially climate-sensitive zoonotic diseases of concern in circumpolar regions (Figure A4). This is not limited to the Arctic; mosquito species that carry viral pathogens such as for dengue fever and malaria are moving northward in southern Europe. About 70% of emerging infections are zoonoses associated with a change in the range zone of vectors, affecting the health of humans in areas where these diseases were not previously found.

Increases in other types of disease associated with climate change include increases in respiratory diseases caused by more molds in houses and other building resulting from more flooding from extreme rain events. The extension of the northern range of trees also creates more pollen and thus increased respiratory illness.

Water security is also becoming a real problem in many areas. In many places, the infrastructure for water provision is outdated. This resulted in outbreaks of cryptosporidium in northern Sweden in 2010 and 2011 during which over 100,000 people were affected and more than 20,000 became ill.

Spreading plants (both native and alien) and changes in species interactions are affecting biodiversity and ecosystem functioning. Plants, animals, humans and pathogens in the vulnerable cold ecosystems of mountains and the far north have thus far been neglected by scientists as well as policymakers. It is important to work across disciplines to address emerging biosecurity issues in cold environments.

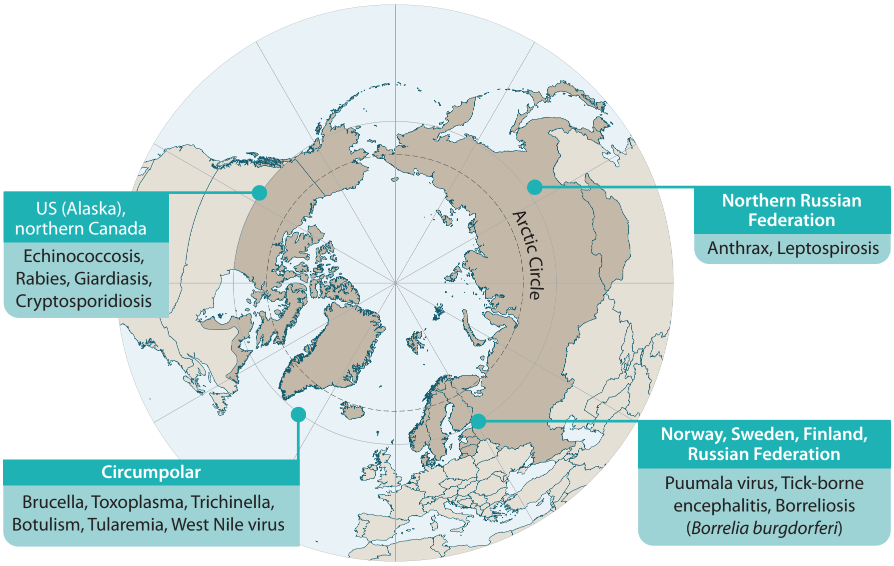


Figure A4 Examples of zoonotic diseases that are potentially climate sensitive in circumpolar areas. Source: Umeå University.

Under the Millennium Development Goals, there is now less poverty in the world than there was twenty years ago, but the impacts of climate change are diminishing these advancements. These goals have now been replaced by the Sustainable Development Goals, and it is important to associate with these goals in the further development of health-related research in the Arctic.

To better understand these changes and combat their effects, cooperation among Arctic countries should be strengthened and international networks should be further developed on health issues. Priority issues include mental health; vectorborne infections; modeling ecological changes such as range shifts, temperature changes, and changes in precipitation; increased and better national monitoring; and communication of the findings to national and local health authorities.

## A3.5 'One Health' as an organizing principle in detecting, assessing, monitoring, and adapting to emerging environmental, human and wildlife health threats

Dr. James E. Berner, Alaska Native Tribal Health Consortium (ANTHC) Anchorage presented information on the 'One Health' initiative. The term 'One Health' refers to a holistic view of all components of the ecosystem that regards all components, living and non-living, as an interconnected whole, with every change in any component (human, animal, environment) eventually having a potential effect on the health of the others.

In order to create a framework to approach the research needs of human residents in the Arctic, the ANTHC has elected to view the emerging environmental health threats in terms of food and water security, and threats to village infrastructure. These elements are among the most critical to community health and sustainability. The definition used for both food and water security is: adequate amounts, adequate access, and adequate information about safety of the resource.

Existing research has documented three basic environmental threat categories: anthropogenic contaminants, warming air and water temperatures, and zoonotic and other microbial threats. Others exist, such as resource extraction industries, and rapid socio-cultural change, but these will not be discussed here.

A critical requirement for identifying priority issues for human health research and evaluating interventions is an interested community, equipped to observe the local environment and to regularly monitor key elements, and willing to participate in creation of adaptation strategies based on the data gathered. Examples of these community-based monitoring efforts covering a spectrum of environmental threats identified in rural Alaska are presented here, together with potential possibilities for partnering with other circumpolar countries.

The Rural Alaska Monitoring Program (RAMP) has been designed by the ANTHC to monitor the Bering Strait region's climate-impacted threats to human and wildlife environmental health. RAMP uses a 'One Health' framework, which assumes that all parts of the environment and ecosystem are related and are affected by changes in any other part. The particular focus of monitoring is on food and water security in rural Alaska, where Arctic warming, anthropogenic contaminants, and disease-causing organisms interact to form threats to food and water security (Figure A5). The changes in the climate, landscape and wildlife species result in a sense of loss of control in the residents of small communities, so the RAMP monitoring components provide a means for residents to participate in tracking their environmental threats; they also decrease the sense of powerlessness in the face of the changing environment, reducing stress. The RAMP monitoring components include:

- Measurements of antibodies in the blood of terrestrial and marine mammals collected by soaking filter paper in hunter-killed animals to indicate exposure to diseases that can infect both animals and humans, i.e., zoonotic diseases. In the future, this blood will also be tested for the presence of environmental contaminants. Filter strips with animal blood are dried, put into an envelope, and sent for testing.
- Sampling the stomach and intestinal contents of marine mammals to test for the harmful algal bloom toxins saxitoxin (causing paralytic shellfish poisoning) and domoic acid (causing amnesic shellfish poisoning).

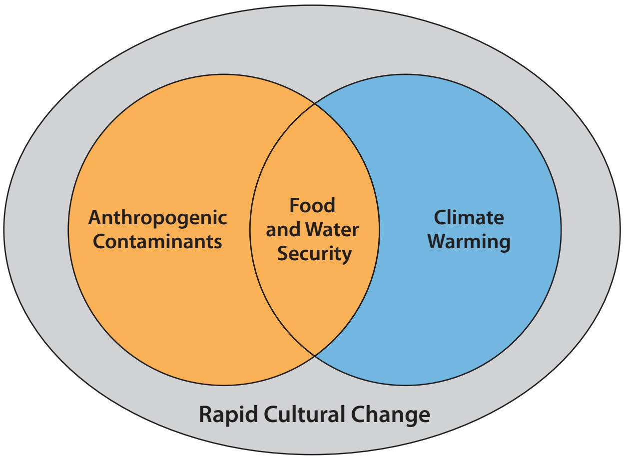


Figure A5 A confluence of changes affect rural Arctic communities.

- Testing ticks and mosquitos for the bacteria that cause the tularemia infection, a zoonotic disease of beavers, muskrats and rabbits, which are species that have moved north with the northward shift of the tree line.
- Testing local freshwater sources for the presence of mercury, which is a mix of naturally occurring local mercury and mercury transported via air from Asian power plants. Mercury, as deposited from air or released from thawing permafrost, can be methylated by resident species of bacteria, and the longer, warmer ice-free seasons may well have increased that process. In addition, testing occurs for the presence of harmful cyanobacterial blooms that may occur in freshwater when it warms and thaws permafrost, which can release nitrogen and phosphorus into the water providing optimal conditions for these blooms.

Among the zoonotic diseases, Q-fever, caused by the bacterium *Coxiella burnetii*, is having a major impact on northern fur seals in the southern Bering Sea. These seals, which are an endangered species, show a prevalence of antibodies against the bacterium of 75%. Stellar sea lions in adjacent rookeries on St. Paul Island have a similar prevalence of antibodies to this disease. About 50% of harbor seals have formed antibodies to the toxoplasma gondi parasite and the trichinella parasite is very common in polar bears and walrus. Farther south, the West Nile Virus has moved north into the middle of the prairie provinces of Canada, and there is no reason to expect it will not progress further north.

Anthropogenic persistent organic contaminants, including PCBs, toxaphene, and the DDT group as well as perfluorinated compounds, are released from countries with rivers that empty into the Pacific basin, exposing marine mammals and fish species. Ribbon seals from the Russian side of the Bering Sea have been shown to contain very high levels of DDT in their fat compared to the other species of seal at the same latitude in the Bering and Chukchi seas. Residents of communities on the Chukotka Peninsula are especially exposed to various contaminants in thousands of abandoned metal barrels, which have contained a variety of contaminants, and are buried in permafrost or stored on the surface in nearshore environments.

Health studies of pregnant women in the Yukon-Kuskokwim Delta in Alaska show that the exposure of young mothers to mercury and organic contaminants has not increased over the 13 years of monitoring, but that many of these mothers, and especially their newborn infants, have low levels of vitamin D. Vitamin D deficiency, with visible bone deformities, has begun to be recognized increasingly frequently in Alaska Native children. Pregnant women in this region with deficient levels of Vitamin D are also more likely to have other clinical findings of insulin resistance, and are thus more likely to develop Type 2 diabetes mellitus. The gradual change in diet to a greater proportion of western foods, and away from the prior high-vitamin-D traditional diet, may contribute to this problem.

Research needs include the necessity of continuing to monitor maternal contaminant exposure and vitamin D intake, with long-term follow-up of mothers and their infants to detect health effects in the foreseeable future, as contaminants continue to be distributed by oceanic, riverine and atmospheric transport.

There is also a need to continue testing of appropriate marine mammal tissues for harmful algal bloom toxins. High-performance liquid chromatography (HPLC) investigation of the variant forms of saxitoxin in ice seal tissues should be conducted in different parts of the Arctic to determine whether the toxin is being formed by the same plankton species in all Arctic regions. Investigations should also begin on effects of harmful algal toxins on marine mammal genes.

Consideration should be given to widespread testing of circumpolar populations for vitamin D adequacy, with prioritization of maternal populations entering prenatal care and sampling of newborn cord blood; inadequate levels should be handled with early aggressive replacement therapy.

Large-scale investigations could be conducted of vitamin D-associated genes in different Arctic human populations to determine whether different population groups have variations in what is an adequate measured level of vitamin D.

Consideration should be given to standardizing zoonotic antibody testing for a range of infections found with a circumpolar distribution. Consideration should also be given to establishing a network of rural hunters willing to use filter papers to take blood samples from harvested animals. This would enable the tracking of trends in zoonotic infection and contaminant exposure and the movement of pathogen species among regions; it would also assist the establishment of a circumpolar archive of specimens.

Consideration should be given to the development of a circumpolar biomonitoring strategy that includes both humans and key wildlife species, and would provide data on exposure to contaminants, zoonotic pathogens, and harmful algal bloom (HAB) toxins. The strategy should be specific for each region, with standardized laboratory techniques, and should utilize existing data to design and take advantage of pooled specimens, use of stable isotope techniques to replace standard dietary surveys (where feasible), sampling at two- to three-year intervals and, where possible, sample limited numbers of forage species at a lower trophic level (such as Arctic cod or representative runs of salmon).

The objective of such a strategy would be implementation of a biosampling plan that would provide statistically significant trend data for contaminant levels, zoonotic pathogen exposure, and HAB toxins, with less cost and labor than a more intensive program.

### A3.6 Discussion of research needs related to combined effects of climate change, contaminants, and zoonotic diseases in the Arctic

In the discussion, a number of topics were identified for future research. Many of these topics are already being investigated in some regions.

***Monitoring of contaminants, zoonotic pathogens and harmful algal bloom toxins***

Monitoring programs for contaminants in animals are currently being conducted on a local and national basis and the data are usually published quickly and are readily available in national and international literature. Contaminant data on humans in the Arctic are largely contained in the published AMAP Human Health Assessment Reports. It was suggested that AMAP might be an organizing entity to encourage the design of a long-term human and subsistence wildlife monitoring strategy utilizing existing programs, that would reduce costs without sacrificing trend data, as described above.

Research on the most effective method of establishing local capacity for hunters to use inexpensive filter paper blood sampling of subsistence species should be considered by all circumpolar countries. Ideally, synchronization of laboratory techniques would produce comparable data for human health and wildlife agencies on exposure to contaminants, zoonotic pathogens, and HAB toxins.

Harmful algal bloom toxins have been found in marine mammals and other species in the northern Bering and Chukchi seas, and research is needed to better define the toxins and organisms responsible.

There is a need for research on the northward movement into the Arctic of species of fish, marine mammals, and terrestrial wildlife, as well as zoonotic diseases.

***Monitoring of drinking water sources***

Monitoring of permafrost temperatures around surface water sources in permafrost-dependent regions should be seriously considered. Drinking water sources in the Arctic are at risk. Ponds on tundra are drying up owing to greater evaporation, while in other cases the thawing of permafrost containment has caused ponds to drain down through the soil.

Monitoring the presence and levels of total mercury and methylated mercury in surface ponds as well as testing for cyanobacteria toxins, especially in prolonged periods of warm weather, should be considered.

***Human health***

Low vitamin D levels in many rural Alaska Native mothers and infants indicate the need for vitamin D assessment in pregnant women in other Arctic populations. These measurements are inexpensive and, if treated early, can prevent much morbidity in these populations.

Research on the impact of climate change on the mental health of people in the North and the Arctic should be considered. They are most affected by the environmental changes that impact culturally critical and nutritionally important traditional subsistence activities. These environmental changes result in a sense of loss and may include depression or other mental health problems.

***General issues***

There is a need for greater international cooperation on health research in the Arctic and this should also include the Russian Federation.

The IPCC Working Group II did not include much information on the effects of climate change on health, mainly because it was difficult to clearly attribute these impacts to climate change. A stronger attribution to climate change is needed for health to be included in IPCC reports. However, the World Health Organization has now labelled malaria and dengue fever as climate-related.

## A4 Mental health and wellbeing in Arctic communities

### A4.1 Promoting resilience and wellbeing

Dr. Stacy Rasmus, Center for Alaska Native Health Research, University of Alaska Fairbanks, stated that from colonialism to climate, Indigenous people in the Arctic continue to experience threats to their overall survival and sustainability and must continually innovate and adopt new strategies for social persistence, adaptation and transformation in the face of global change. New threats arise from the new and changing conditions. Today, Indigenous people in the Arctic find their greatest threats to survival coming not only from the environmental factors that predict conditions of the ice but from the social and relational processes that determine individual and collective community health and wellbeing. Throughout the generations, Alaska Native people have developed strategies and valuable expertise in mitigation of situations of risk and vulnerability.

Social or social-ecological resilience is a construct useful in understanding the ways that Alaska Native and other Indigenous peoples are coping, adapting and transforming in the face of rapid change. The concept of resilience, while gaining wider application in research related to drivers of change and impacts on culture, environment and health, is not often clearly defined and even less rarely understood from an Indigenous perspective. Resilience in an ecological perspective is the maintenance of structure and function under disturbance. In psychology, resilience implies the ability to cope with and overcome adversity and continue normal development, i.e., managing changes throughout life. It also covers the ability to learn from past experience and adjust to future challenges. Linked to the notion of resilience is the concept of wellbeing as a more holistic health indicator.

In the Arctic, the weather is changing with the people. Human impacts on the environment are changing the climate. In Alaska, the Yup'ik have faced many changes throughout their lives, and continue to work to enhance wellbeing by promoting strength, health and coping. One example of an action to enhance wellbeing is the use of Indigenous constructs of resilience and wellbeing as they are applied in the context of a Yup'ik Alaska Native community to reduce youth suicide and alcohol risk as well as to increase strengths and reasons for life. This application is in the form of a Qungasvik or toolbox, which provides a model for promoting reasons for life and wellbeing in Yup'ik and Cup'ik communities, and thus is specifically developed for the cultures of these communities. The Qungasvik comprises the following terms: protective factors (teachings, words to live by, instructions); self-efficacy (I can); communal mastery (we are strong); wanting to be a role model (I want to lead); giving (compassionate, a caring, loving person); affection/recognize (to be thankful to); clear limits and expectations (instruction, rule); family models of sobriety and wellness (ones that are respected); safe places; opportunities (opening their future); role model (good provider); and village rules (village warnings). Six communities in southwest Alaska have taken a similar approach to protect their youth.

In identifying research needs for Arctic health and wellness, the following questions should be considered: How is resilience defined in a culturally and ecologically-specific context? How can we move beyond defining resilience and wellbeing to conduct interventions that promote and support it at the local level? What is an Indigenous 'life lived well' in the Arctic? What other examples exist in the Arctic that demonstrate Indigenous social resilience and wellbeing, as defined by the coping, adaptive and transformative capacities of social-ecological systems and communities? How can wellbeing, as embedded with Indigenous value systems, provide key access points to culture in interventions? How can research promote Indigenous resilience and wellbeing in the Arctic?

## A4.2 Moving beyond preventing suicide individual by individual: Making a case for more collective and community systems interventions

Dr. Diane McEachern, Assistant Professor, University of Alaska Fairbanks, Kuskokwim Campus, Bethel, Alaska, stated that youth suicide is a tragic and pressing problem that plagues Northwest Alaska disproportionately when compared to other areas of the United States. These rural Indigenous communities suffer from one of the highest youth suicide rates in the world. Previous research has shown that Indigenous suicide is associated with cultural and community drivers, namely social disorganization, culture loss and a collective sense of disempowerment. Similarly, lower suicide rates, fewer incidences of alcohol abuse and increased wellbeing have been associated with community connectedness, spirituality, family involvement, intact community services and systems, and cultural affinity for Indigenous people. Despite the established connection between personal, family and community, spirituality, and Indigenous health, behavioral health services are often individually focused and clinically based. This approach ignores the spiritual, family and community-level factors shown to be protective and culturally important, and results in services that can be culturally incongruent and under-utilized in tribal communities.

There is a need for research and program development that is community-driven and thus more in line with community-level factors shown to be protective and culturally important. The typical 'gatekeeper approach' to suicide prevention is based on packaged training of individuals, teaching of risk factors and signs, and is standardized (one size fits all) and de-contextualized; there is mixed evidence of its efficacy although it improves the ability to speak about the problem.

An interdisciplinary alternative is needed to provide a holistic approach; this must be community-driven. It should take an epidemiological approach to the problem, determining who, where and what is associated with it and when the problem occurs (seasonally and historically). It should also determine how people make sense of the problem and respond to it (in narrative and ethnographically). It should consider what community and sociological conditions contribute to 'the problem' or are correlated with its reduction. There is also a need to determine the next important steps for knowledge generation and dissemination to improve the health of Arctic people.

This new approach should be community-driven and evaluated. It should acknowledge community members as a source of knowledge and build on the lived experience of participants in the program to inform action. It can draw from popular education models to develop critical consciousness and activism to empower and transform their societies. It takes a village, and all organizations within it, to prevent suicide. Community members are best able to prevent suicide and promote wellness. However, scientific research is useful to strengthen and guide village efforts. Arctic health research efforts should partner with tribes, organizations and other community structures (including sharing funding with them) and build onto local systems. Research outcomes should provide resources, insights or tools to communities and organizations so that they can most effectively work toward health equity.

One example of such an approach being implemented in an Alaskan community is the National Institute of Health-funded PC-CARES: Promoting Community Conversations about Research to End Suicide. Under this initiative, the community gathers together once a month for about two or three hours to consider the findings in a piece of research. After a brief summary of the paper, the community breaks into small groups and discusses the findings and whether and how they could be applied in their community. This is a slow process, running over about eight months so that the concepts have time to be understood and incorporated in community thinking.

## A4.3 <u>R</u>educing the <u>I</u>ncidence of <u>S</u>uicide in <u>IN</u>digenous <u>G</u>roups – <u>S</u>trengths <u>U</u>nited through <u>N</u>etworks (RISING SUN)

Dr. Pamela Collins, Director of the Office for Research on Disparities and Global Mental Health, National Institute of Mental Health (NIMH), Bethesda, MD, stated that mental disorders are ubiquitous throughout the world. Disabling mental and behavioral disorders are unique among non-communicable disorders because of their high burden in youth through middle age. Suicide rates are very high internationally and are the leading cause of death among older teenage girls. Within the Arctic, the highest suicide rates are in Chukotka, followed by Greenland and Nunavut, and then the other areas in the Russian Arctic. The highest rates of suicide in Alaska are among Native men.

In 2014, the National Action Alliance for Suicide Prevention published 'A Prioritized Research Agenda for Suicide Prevention: An Action Plan to Save Lives'. In this report it is noted, however, that 'A research document alone cannot reduce suicide deaths or attempts; rather, its intent is to identify the research needed to guide practice and inform policy decisions across many areas…'.

Under the Canadian Chairmanship of the Arctic Council, the Sustainable Development Working Group held a Mental Wellness Symposium in March 2015 to summarize the initiative on mental wellness under their chairmanship and to launch the initiative's final report. This symposium's participants presented findings from two projects that mapped interventions for mental wellness and suicide prevention in Arctic Indigenous communities. The authors of the report on the mental wellness initiative noted that solutions must be culturally grounded, community-based and community-driven, with intervention specificity for communities. It is also important to have culturally appropriate shared interventions across communities, including mental health services and intersectoral cooperation. Studies should be solution-focused instead of problem-focused and there should be rigorous evaluation of the results. Furthermore, while there is an elevated risk of suicide in remote, rural, Arctic communities, there is considerable variation in rates. However, standard research approaches to evaluating the effectiveness of interventions in these communities are challenging owing to geographical isolation and small populations.

Building on the Canadian activities, the RISING SUN initiative has been established under the 2015–2017 U.S. Chairmanship of the Arctic Council. RISING SUN is designed to create a common way to evaluate suicide prevention interventions across the Arctic. The use of outcomes and common assessment measures – developed in collaboration with Indigenous peoples' organizations (i.e., Arctic Council Permanent Participants), community leaders, and mental health experts – will facilitate data sharing, evaluation, and interpretation of interventions across service systems in the Arctic. The ultimate goal is to generate shared knowledge that will aid health workers in better serving their communities and help policymakers measure progress, evaluate interventions, and overcome regional and cultural challenges to implementation. Arriving at common outcomes, measures, and reporting systems is especially important in the Arctic, where the vast geography, high number of remote communities, and breadth of cultural diversity pose challenges for systematic approaches to suicide prevention.

The method for achieving the goals of RISING SUN is consensus building, through an adaptation of the Delphi method, as well as regional face-to-face meetings with local stakeholders. For the Delphi method, a panel of over 200 scientific, technical, and traditional knowledge experts was invited to establish a convergence of opinion over the period of the initiative. Panel members have been selected to represent the diverse advocacy, clinical, policy, research, and survivor groups with interests in suicide prevention among Arctic Indigenous communities. To incorporate the viewpoints of additional key stakeholders, three regional face-to-face meetings will integrate local perspectives in consensus-building and priority-setting.

The first of three workshops was held in Anchorage, Alaska, in September 2015, with the purpose of understanding the current suicide prevention landscape across the Arctic and the accomplishments of partnering countries, reviewing the aims of the RISING SUN initiative, and eliciting feedback on efforts to develop an Arctic-specific suicide prevention toolkit. Presently, RISING SUN is conducting the consensus-building activity and planning for the second workshop, scheduled for May 2016 in Tromsø, Norway. This meeting will convene participants to review stakeholder feedback, come to consensus on the best outcomes and measures available, specify gaps in available measures that may require further development, and identify potential implementation challenges. At the end of the initiative, RISING SUN will result in a toolkit of common outcomes and their measures for suicide prevention efforts, applicable across the Arctic, which could expand Arctic states' capacity to evaluate the implementation of evidence-based interventions to combat suicide.

### A4.4 Discussion on suicide prevention and mental wellness

Regarding the very high rates of suicide in the Russian Arctic, especially in Chukotka, it was noted that there are many other health problems in Russia and longevity is low. Under a U.S.-Russian collaboration, data are being collected on suicide, infectious diseases and many other diseases in people in Chukotka and a course is being developed on health and safety for this region. Another project, financed by the U.S. National Science Foundation, is bringing together a large number of Russian Indigenous people and Yup'ik from Alaska to explore their views and experiences based on a common set of questions. Reports will be prepared on the outcome of both of these initiatives.

The development of toolkits, such as the one constructed for the Yup'ik in Alaska and those in development under RISING SUN, to prevent youth suicide and create healthy communities was considered very important. They are particularly needed when a small community suddenly experiences a rapid rise in the number of suicides among young people, leaving the community shocked, scarred and feeling helpless. There is a need to build up a healthy community premise, arising from strength-based foundational work.

Youth are at risk, often high risk, in their communities. Communities need to be taught that resilience is a strength-based process. Protective factors based on strength provide building blocks in their culture. Resilience should be considered beyond the individual level and more at a community level. However, some consideration may need to be given concerning the relation between communities and health professionals in terms of treatment. There is a need to balance how to help individuals and the community approach to wellbeing.

Furthermore, the community basis to determine what is protective against suicide should be more holistic, not just to stop suicide but to give youth reasons for living, as guided by elders. Protective factors need to be enhanced as young people go through the activities prescribed by the toolkit. To determine protective factors relevant to a specific community, the U.S. National Institute of Mental Health has published a research concept (and now a request for applications as of 22 March 2016) focused on stimulating collaborative research with American Indian and Alaska Native communities regarding suicide prevention.

## A5 Public health and community services

### A5.1 Community health perspectives

Dr. Gert Mulvad, physician, Greenland Center for Health Research, University of Greenland, Nuussuaq, described the approach to community health in Greenland. A community health perspective can be gained from a local exhibition of words: 'Assiliaq', meaning humor and childhood, as well as from four concepts from the report 'High level determinants of community wellness, Fulbright Arctic Initiative on Community Health and Wellness in The Arctic: Capacity Building, Training in Communities, Rapid Transitions, and Cultural Connection'. Despite serious challenges, Arctic communities have proved resilient in adapting to environmental and social change. However, large challenges remain and new partnerships between scientists, medical professionals, and communities are essential to increase local capacity, participation and control over health care and wellness programs. The view of community health issues in the Arctic region is shifting from one solely based on problems and deficits to one that builds on examples of community resilience, promotes capacity building, and disseminates successful outcomes. Furthermore, the focus on children, family values, family traditions and family responsibility is becoming increasingly important in rapid changing communities. This focus on family values and the health and wellness of children and youth as the key priorities is part of the Inuit Circumpolar Council (ICC) Strategy for Family Health and Wellbeing. This strategy emphasizes selflessness, sharing and respect for each other, as well as fostering traditional values with the help of elders in the community. It also emphasizes the need for individuals to take responsibility for their own health and families to take responsibility for the health and wellness of their children. Communities must also take ownership over responses to emerging crises and rely less on external support.

Capacity building is required to develop new graduate and medical training programs that instill a better understanding of research ethics and responsibilities when working with communities, and promote an appreciation of the values of traditional knowledge in forming research plans and relationships with communities. Researchers should be encouraged to form authentic partnerships with local communities based on questions developed in cooperation with the community and designed to produce tangible benefits to the community. Social-ecological restoration needs to be incorporated as a component and measure of community health. It is also necessary to increase the number and quality of professional health staff, particularly Indigenous people with native language skills. The local capacity of current health programs to meet the physical and mental health needs of individuals and the community is highly strained.

To meet these aims, the Greenland Center for Health Research is developing PhD courses in Greenland to develop knowledge to elevate the health status in Greenland to its optimum level. The University of the Arctic and Oulu University in Finland offer a Master of Science course specializing in health and the environment in Greenland and in the Arctic. The aim is to enhance capacity building to develop new graduate and medical training so that about 50% of the nurses and 15% of the doctors will be Inuit.

In communities, there is a need to place health education, programs and services in a holistic framework of personhood that links personal responsibilities for health with social obligations to family, neighbor, and community. Furthermore, it is not possible or desirable to separate the health of Arctic residents and communities from the health of their culture, language, and educational systems. Innovations in community health care delivery need to be based on the level of community involvement and local determination of health care benchmarks. This involves reframing health research from a problems-and-deficits model to one seeking to understand what protects community health. This approach necessarily draws upon traditional knowledge, culture, spirituality, language and local resources to define community-based solutions to health challenges. Health care solutions to problems in the North will require practices and solutions designed by people of the North in collaboration with 'outside' expertise.

Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Climate change is having an impact on fisheries, agriculture and wildlife harvesting, and globalization affects trade, with a focus on fisheries in the Arctic for local food and commercial interest.

As Arctic societies develop at record-breaking speed both economically and politically, the traditional family structure has been transformed. Norms and value systems, including gender and intergenerational relationships, have also changed dramatically. With these changes within society, many social and psychological problems have been brought to the surface. The family has always been the basis for childhood; it is necessary to maintain the family perspective in a community in transition. Priority needs to be given over the next decades to ensuring that children grow up in the family and that community services are available for childcare, development and training. Schools must have the necessary resources as well as appropriate educational and professional tools, with the family in focus, to create a much closer collaboration between health care, social services and the school system. The rapid development in Greenland, with changes in family structure, labor and economy, has created a need for a functioning social service to alleviate losses in the wake of these developments. A close collaboration between health, social and educational systems must lay the groundwork for better welfare for families in Greenland.

Welfare is about social and economic security for citizens. People in the North have a desire to be economically independent in the future. Innovative research in fisheries, mining and infrastructure can be the way to attain economic independence, but local capacity building is an essential issue for this development.

## A5.2 Public health infrastructure

Dr. Ali Hamade, Environmental Public Health Program Manager, Division of Public Health, Alaska Department of Health and Social Services, described the challenges to public health services in Alaska. It is the largest U.S. state, but has the lowest population density. Of the roughly 737,600 residents, about 150,000 live in rural communities spread over the immense state and its thousands of islands. Several entities contribute to Alaska's public health infrastructure. These include the Department of Health and Social Services, Department of Environmental Conservation, Municipality of Anchorage, the Alaska Native Tribal Health Consortium, Native Health Corporations, clinics, the Centers for Disease Control and Prevention, the healthcare community, and others. These agencies collectively aim to protect and promote the health of Alaskans by independently and collaboratively fulfilling needs related to disease surveillance and tracking, health promotion and disease prevention, women and children's health, vital statistics, emergency preparedness, health planning and health systems development, chemical and infectious agent testing laboratories, epidemiology, toxicology, vaccinations, and nursing. Alaska constituents and stakeholders in public health are engaged directly and indirectly by providing services, sharing public health findings and recommendations, and addressing health questions and concerns. Independent efforts are augmented by strong partnerships and collaborations among state, tribal, local, federal, and private entities.

In the public sector, 20% of Alaskans are served by the Alaska Tribal Health System and 12% by military and Veterans Administration systems. The remainder is served by state and local clinics and hospitals and the private sector facilities. There is, however, a shortage of health professionals in many areas. The Alaska Native Tribal Health Consortium offers services in a broad range of health-related issues, from rural energy and clean water and sanitation to behavioral, environmental and community health. The Alaska Division of Public Health offers a wide range of health services and facilities, and develops health care policy and regulations. The broad reach of Division of Public Health Services is exemplified by the Section of Public Health Nursing, which operates 21 public health centers from which nurses travel mainly by air to remote interior or island communities to provide health care. Partners in public health include communities, the Department of Environmental Conservation (covering environmental health, sanitation and hygiene, and public drinking water systems, among other areas), tribal health systems (with 150 to 200 small clinics) and various federal agencies.

Three major challenges to public health in Alaska include adequate rural facilities, food safety and security, and wildfire preparedness.

Adequate facilities in rural areas are not always available to support access to medical care. This includes the need for improved landing strips for aircraft carrying health care personnel and to facilitate medical evacuations in some remote rural areas. Moreover, road maintenance is needed for ease of transportation within communities. Unpaved roads with inadequate dust palliative application foster dust generation and air quality decline.

Food safety and food security represent another important challenge facing Alaskans. The subsistence food harvest is associated with many important nutritional, cultural and spiritual values. The changing climate is affecting the traditional harvest and impacting traditional methods of capture or hunting and food preservation methods. New insecurities arise from the occurrence of harmful algal blooms resulting in shellfish toxins as well as potentially changing levels of environmental contaminants in wildlife species. As a result, monitoring for contaminants and toxins in food samples and preparing guidelines for consumption of fish and marine mammals are increasingly important.

Wildfires have been intensifying over the past few decades and there is a need for broader coverage of contingency and preparedness plans for villages with regard to evacuation and restoration after the fire is over. Current air quality monitoring and modeling could be augmented, and there are deficiencies in clean and safe capacity for sheltering in place. A Local Environmental Observer program has been established throughout the state to share environmental observations and other information.

The 'Healthy Alaskans 2020' initiative, co-led by the Alaska Department of Health and Social Services and the Alaska Native Tribal Health Consortium, provides a framework to support the work of partners and stakeholders throughout the state. It prioritizes 25 health objectives for the decade that include cancer, suicide, interpersonal violence and sexual assault, alcohol, tobacco and drug use, and obesity.

### A5.3 Technological aids: Telehealth and Technology in Alaska

Garret Spargo, Director of Product Development, Telehealth Department, Alaska Native Tribal Health Consortium, stated that he has a program to help select appropriate telehealth systems. In this context, the term 'telemedicine' means the 'delivery of billable, interactive clinical services performed at a distance', while 'telehealth' is a broad category covering 'the use of electronic information and telecommunications technologies to support long-distance clinical health care, patient and professional health-related education, public health and health administration'.

Telehealth technology is used by different facilities. In hospitals and specialty clinics, specialists see and manage patients remotely, making sure that patients follow up properly. In integrated care facilities, mental health and other specialists work in primary care settings to aid patients. For situations of transition and monitoring, patients access care (or care accesses patients) where and when needed to avoid complications and the need for higher levels of care. The technology requirements vary depending on the purpose.

The main types of technology are:

- *Live videoconferencing (synchronous)*: This is a live, two-way interaction between a person and a provider using audiovisual telecommunications technology. This, however, requires internet connectivity to the site with the patient, which is not always possible in remote areas of Alaska.
- *Store-and-forward (asynchronous)*: This provides for the transmission of recorded health history through an electronic communications system to a practitioner, usually a specialist, who uses the information to evaluate the case or render a service outside of a real-time or live interaction.
- *Remote Patient Monitoring*: This involves the collection of personal health and medical data from an individual in one location via electronic communication technologies, which is transmitted to a provider in a different location for use in care and related support.
- *Mobile Health*: Under this, health care and public health practice and education are supported by mobile communication devices such as cell phones, tablet computers, and personal digital assistants (PDAs). Applications can range from targeted text messages that promote healthy behavior to wide-scale alerts about disease outbreaks, as just a few examples.

The Alaska Tribal Health System, a voluntary affiliation of 30 Alaskan tribes and tribal organizations that serves approximately 140,000 Alaska Natives across the state, 70% of whom live in rural communities, uses telemedicine carts as a primary care tool (Figure A6). Instruments on these carts can test for ear disease, heart disease, and respiratory illness, and have a digital camera to view wounds and skin diseases, as well as a dental camera. A scanner is also attached. Cases reviewed in a village are transmitted to a specialist in a relevant remote clinic who then makes treatment recommendations. A large number of specialty healthcare clinics are available by video-teleconference, including clinics in other states for certain specialties.

Figure A6 Telemedicine cart used by the Alaska Tribal Health System. Source: Garrett Spargo.

A review of the experience of healthcare providers on their use of telehealth over the past 15 years indicated that three quarters felt that telehealth improved the quality of care for the patient, while two-thirds indicated that use of telehealth improved patient satisfaction. Waiting time for diagnosis has also decreased significantly, with 25% of cases turned around in one hour and 60% of the cases turned around on the same day. Another advantage of the increasing use of telehealth in Alaska has been a large saving in travel costs for patients and the health system.

In a supplementary presentation, Dr. Sven Ebbesson, a long-time physician-researcher retired from the University of Alaska Fairbanks, described his 20 years of work to determine the key risk factors for coronary disease and diabetes in Alaska Natives. The study concentrated on 13 villages in the Norton Sound area, where the local communities are now experiencing high rates of coronary disease, diabetes and stroke. Whales, seals and fish, which have very low levels of saturated fats, had been the traditional diet of these communities for over a thousand years, and until 1970 diabetes and coronary heart disease were very rare. However, since then convenience food stores arrived, bringing processed foods with high levels of saturated fats including products such as shortening, which contains 25% saturated fat. This dietary shift from highly unsaturated to more saturated fats currently experienced by Alaska Natives presented an exceptional opportunity to study the effects of such changes on health. Based on the risk factors determined, a food guide was prepared to recommend which foods to avoid and which foods are healthy. As part of this National Institutes of Health-funded work, over 8000 house visits were made to explain the study and its results and to encourage good dietary habits and adequate exercise.

### A5.4 Discussion on community health and telehealth examples

While telehealth is available for a large and growing range of physical health conditions and diseases, there have been difficulties in establishing behavioral health aids in telehealth. There has been a lack of professionals to assist in behavioral telehealth so far. Another issue regarding telehealth in the U.S. is that few insurers pay for telemedicine services and some physicians are wary of possible malpractice suits against them.

Regarding research partnerships in the North, Inuit consider themselves 'the original Arctic scientist'. It would be advantageous to make PhD opportunities more accessible in the North as communities can do much more regarding research in partnership with universities and other research organizations. Furthermore, such research should also include the impact of government policies that may have more impact on an Indigenous community than climate change.

It would be useful to link case studies across borders. Building local capacity and strengths is also important and consideration should be given to how to support more capacity building for researchers and health professionals. It is very important to connect research with education. When doing research in the North it is not always easy to do education in the North, so the possibility of connecting research with education should be increased. Collaboration in the North is of great importance and is particularly needed for capacity building. Capacity building is important; Indigenous groups should not be seen as a charity case – they want to be part of the process.

Regarding research priorities, it is important to move away from geographical and disciplinary silos. Indigenous organizations conduct good research. There is a need to hear Indigenous voices and for Indigenous leadership to set priorities with and for the broader health research community. Climate change will impact everything. There is no health without mental health.

More intervention studies and research are needed, not only to examine an interesting idea but for the purpose of helping people. There is a need to educate people in the villages, to teach young people how to cook and choose a healthy diet. Diet is the most important factor in disease and also the most possible to change.

## A6 Panel discussion – research needs for Arctic health and wellness

One proposal was to build on the work that the AMAP Human Health Assessment Group has coordinated for over 20 years. The core of this program has been to collect biomonitoring data on the exposure of Arctic and Northern residents to environmental contaminants arising primarily from dietary sources and, more recently, related studies on the health outcomes and effects that may be associated with these contaminant exposures. However, public health professionals ask questions regarding health on a much broader basis. Obtaining a good dataset both on public health variables and on contaminants could provide a full picture of the exposure of children. This could be combined with a genome study. If this could be conducted on a broad basis in the Arctic and North, covering social and mental conditions and contaminant exposures and comparing with different genetic backgrounds on a circumpolar basis, a very powerful dataset would be established. The methodology could employ the use of blood samples on filter paper from humans and also from animals hunted for food. It takes a good amount of work to establish such cohorts, but data can be harvested for years to come. The breadth of this proposal includes the suicide issues discussed earlier, and can explore why 15-year-old children have thoughts about death: is this new or did we just not see this before? Results will be useful from both the environmental health and public health perspectives.

This proposal was seconded by another panelist. There are already a number of cohort studies in the Arctic and it would be good to follow them prospectively on a broader public health basis.

This proposal also emphasizes the importance of public health professionals working with veterinarians; much better collaboration is needed between these groups to tackle the spread of zoonotic diseases. As climate change has, and will continue to have, a rapid and significant impact on the ecology in the North, vectors for infections will change their habitat and have an impact on the health of animals and humans. To monitor this change, longitudinal studies are of value and stress the need for not only regional and national surveillance but also international collaboration, which is very important and should become more pro-active, for example, with regard to sustainable development goals. As the Russian Federation constitutes a large part of the Arctic, it is particularly important to have Russia included in these collaborations.

The presentations showed a clear need for multilevel interventions regarding mental health and wellness. A program is needed to determine what works and how to bundle together and package interventions to mitigate social disruptions, as well as how to disseminate the ideas so that others can adapt and use them. Capacity building for research in these communities is very important. From a funding perspective, there is an issue of how to ensure that the research makes a public health intervention effective; for this there is a need for partnerships between governments and end users.

Northern populations are very resilient; they have a survival instinct that may have been lost by other populations, but now they feel that there are new threats that they cannot see. It is important to develop communication tools to help them learn about these threats and to monitor them. Furthermore, some Indigenous tribes no longer have a single village that is solely theirs. It would be useful to build a more centralized way to share with all communities; to build a tool for managers. As health issues are impacting Indigenous populations disproportionately, there is also a need to move from interventions to broader wellness measures.

A participant quoted from a Yukon First Nations report prepared 43 years ago: "We must decide what research needs to be done and who will do it and include our own people so we can learn to do it on our own, We need to own the results of the research so it can be used." However, it was pointed out that some organizations that were not participating in this workshop represent large Indigenous groups who have their own research agendas. Work is needed regarding dissemination of scientific findings. Many communities are experiencing rapid change and are very interested in these types of research; although it may be difficult to include them, it is important to do so.

Accordingly, there is a need to have research generated from Indigenous communities, based on Indigenous leadership and priorities, as well as to have translational research to take research results to Indigenous communities in a way that they can most easily apply these results. Western researchers and social workers have been trained to view Indigenous people as clients, not as equals; there is a need for such workers to reflect and challenge themselves about their role and position and how to work cross-culturally and collaboratively on research. This is beginning to change as more Indigenous people earn PhDs and other professional degrees and become colleagues and more integrated in the research process, and as more Indigenous leaders, organizations, and communities are taking greater control of the research agenda to steer research so that results are useable and meet needs and priorities. Classically trained researchers are now also being exposed to more participatory research designs and indigenous ways of creating and sharing knowledge, thus enhancing and enriching this collaboration.

## A7 Final remarks

The facilitator Rhonda Johnson thanked the speakers and participants for their contributions to the workshop. On behalf of AMAP, Lars-Otto Reiersen expressed his appreciation, noting that much good information had been presented and discussed. From EU-PolarNet, Nicole Biebow stated that the workshop had been very informative, and now the most relevant issues need to be conveyed to the EU-PolarNet consortium.

### Reference

AMAP, 2015. AMAP Assessment 2015: Human Health in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. vii+165pp.

# AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs for Arctic Health and Wellness

Fairbanks, Alaska, 12 March 2016

## Workshop agenda

### Morning session

*Chair:* Lars-Otto Reiersen, AMAP Secretariat
*Facilitator:* Rhonda Johnson, University of Alaska Anchorage

**Opening and welcome**
Lars-Otto Reiersen, AMAP Executive Secretary

**Context of the workshop: Research needs defined for EU-PolarNet work**
Nicole Biebow, AWI, Project Manager EU-PolarNet

**Aims and outcome of the workshop**
Janet Pawlak, AMAP Secretariat – Rapporteur

**Structure and schedule of the workshop**
Rhonda Johnson, University of Alaska Anchorage – Facilitator

**Overall perspectives: Climate change and health in the circumpolar North**
Ashlee Cunsolo-Willox, Cape Breton University

**Local perspectives: Fish and wildlife co-management in relation to health and wellness in the Labrador Inuit Settlement Area**
Jamie Snook, Torngat Wildlife, Plants and Fisheries Secretariat

**Contaminants in Arctic food species: health effects issues**
Pál Weihe, The Faroese Hospital System

**Combined effects of climate change, contaminants, and zoonotic diseases**
Birgitta Evengård, University Hospital, Umeå University, Sweden

**Initiative to build on: One Health: animal, environment, and human health**
Jim Berner, Alaska Native Tribal Health Consortium

### Afternoon session

**Promoting resilience and well-being**
Stacy Rasmus, University of Alaska Fairbanks

**Moving beyond preventing suicide individual by individual: Making a case for more collective and community systems interventions**
Diane McEachern, University of Alaska Fairbanks, Bethel

**Initiative to build on: Rising Sun: suicide prevention**
Pamela Collins, U.S. National Institute of Mental Health

**Community health perspectives**
Gert Mulvad, University of Greenland

**Public health infrastructure**
Ali K. Hamade, Alaska Dept. of Health and Social Services

**Technological aids: E-health and E-welfare**
Garret Spargo, Alaska Native Tribal Health Consortium

**Panel discussion – Research needs for Arctic Health and Wellness**

**Final remarks and closing of meeting**

**Circumpolar Networking Event hosted by the American Society for Circumpolar Health**

# Workshop participants

| Name | Institute |
|---|---|
| Thomas Armstrong | University of Montana, USA |
| Renuka Badhe | European Polar Board Secretariat, The Hague, Netherlands |
| Kristina Bär | Alfred Wegener Institute, Bremerhaven, Germany |
| Julie Benson | Alaska INBRE, Fairbanks, Alaska, USA |
| James Berner* | Senior Director for Science<br>Alaska Native Tribal Health Consortium, Division of Community Health, Anchorage, Alaska, USA |
| Nicole Biebow* | Project Manager EU-PolarNet<br>Head of the International Cooperation Unit<br>Alfred Wegener Institute, Bremerhaven, Germany |
| Sigrid Brudie | University of Alaska, Anchorage, Alaska, USA |
| Pamela Collins* | Associate Director for Special Populations<br>National Institute of Mental Health (NIMH)<br>Director<br>Office for Research on Disparities & Global Mental Health, Office of Rural Mental Health Research<br>National Institute of Mental Health/NIH, Bethesda, MD, USA |
| Ashlee Cunsolo Willox* | Canada Research Chair in Determinants of Healthy Communities & Assistant Professor<br>Community Health Department of Nursing, Cross-Appointed with Indigenous Studies Cape Breton University, Sydney, Canada |
| Björn Dahlbäck | Swedish Polar Research Secretariat, Stockholm, Sweden |
| Juanjo Danobeitia | CSIC – UTM, Barcelona, Spain |
| Irina Dardynskaia | University of Illinois, Chicago, Illinois, USA |
| Robert A. Delgado | Office for Research on Disparities & Global Mental Health, National Institute of Mental Health, Bethesda MD, USA |
| Oleg Doubynsky | University of Illinois, Chicago, Illinois, USA |
| Ruth Driver-Breen | British Antarctic Survey, Cambridge, UK |
| Gunnar Ebbesson | Turning Point Counseling Services, Fairbanks, Alaska, USA |
| Birgitta Evengård* | Professor & Head of the Division of Infectious Diseases<br>Department of Clinical Microbiology, Unit Infectious Diseases, Umeå University, Umeå, Sweden |
| Kelly Falkner | Division of Polar Programs, NSF, Arlington, VA, USA |
| Elaina Ford | British Antarctic Survey, Cambridge, UK |
| Yves Frenot | French Polar Institute (IPEV), Plouzané, France |
| Carolina Cavazos Guerra | Institute for Advanced Sustainability Studies e.V. (IASS), Potsdam, Germany |
| Ali Hamade* | Environmental Public Health Program Manager<br>Alaska Department of Environmental Conservation, Anchorage, Alaska, USA |
| Rhonda M. Johnson*<br>Facilitator | Professor of Public Health & Past Chair at the Department of Health Sciences<br>University of Alaska, Anchorage, Alaska, USA |
| Kirsti Latola | Thule Institute, University of Oulu, Finland |
| Karin Lochte | Alfred Wegener Institute, Bremerhaven, Germany |
| Heather Mariash | National Wildlife Research Centre, EC, Carleton University Ottawa, Canada |
| Diane McEachern* | Assistant Professor<br>Program Head for the Rural Human Service (RHS) program<br>University of Alaska – Bethel, Alaska, USA |

| Name | Institute |
|---|---|
| Gert Mulvad* | Family physician, Centre for Primary Health Care, Nuuk, Greenland & Chair, Greenland Institute of Natural Resources<br>University of Greenland, Nuussuaq, Greenland |
| Gunagshei Na | National Marine Environmental Monitoring, Dalian, China |
| Janet F. Pawlak | Arctic Monitoring and Assessment Programme Secretariat, Oslo, Norway |
| Guy Peters | Alaska Vision, Arctic Wellness & Justice, Fairbanks, Alaska, USA |
| Hild Peters | Alaska Vision, Arctic Wellness & Justice, Fairbanks, Alaska, USA |
| Peter L. Pulsifer | ELOKA Project (http://eloka-arctic.org), National Snow and Ice Data Center, Cooperative Institute for Research in Environmental Science (CIRES), University of Colorado, Boulder CO, USA |
| Antonio Quesada | Universidad Autónoma de Madrid, Madrid, Spain |
| Stacy Rasmus* | Research Associate Professor<br>Center for Alaska Native Health Research, Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska, USA |
| Arja Rautio | Thule Institute, University of Oulu, Finland |
| Lorrie Rea | Institute of Northern Engineering, Water and Environmental Research Center, University of Alaska Fairbanks, Fairbanks, Alaska, USA |
| Lars-Otto Reiersen<br>Chair | Executive Secretary<br>Arctic Monitoring and Assessment Programme, Secretariat, Oslo, Norway |
| Inna Rivkin | Department of Psychology and Center for Alaska Native Health Research, University of Alaska Fairbanks, Fairbanks, Alaska, USA |
| Denis-Didier Rousseau | CNRS - Institut National des Sciences de l'Univers, Paris, France |
| Hannele Savela | Thule Institute, University of Oulu, Finland |
| Patricia Sekaquaptewa | University of Alaska Fairbanks, Fairbanks, Alaska, USA |
| Jamie Snook* | Executive Director<br>Torngat Wildlife Plants and Fisheries Secretariat, Happy Valley - Goose Bay, NL, Canada |
| Frank Marin Sonne | Ministry of Environment and Food, Danish Environmental Protection Agency, Copenhagen, Denmark |
| Garret Spargo | Alaska Native Tribal Health Consortium, Anchorage, Alaska, USA |
| John Stedfman | American Society of Circumpolar Health, Bethel, Alaska, USA |
| Bryan Thomas | Barrow, Alaska Observatory, NOAA, Barrow, Alaska, USA |
| Rein Vaikmäe | Department of Isotope-palaeoclimatology, Institute of Geology, Tallinn University of Technology, Tallinn, Estonia |
| Bob Van Dijken | Council of Yukon First Nations, Canada |
| David G. Vaughan | British Antarctic Survey, Cambridge, UK |
| Gonçalo Vieira | University of Lisbon, Lisbon, Portugal |
| Ruth Vingerhagen | University of Cambridge, Cambridge, UK |
| Pál Weihe* | Head of Department<br>Department of Occupational and Public Health, The Faroese Hospital System, Torshavn, Faroe Islands |
| Jan-Olov Westerberg | Swedish Museum of Natural History, Stockholm, Sweden |

* Workshop presenter and panellist

*Seagulls landing on mouth of humpback whale. Photographer: Dr. Elliott Hazen NMFS/SWFSC/ERD*

PART B

# AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Arctic Ecosystems and Ecosystem Services

Riga, Latvia, 20 September 2016

## Contents

# Executive Summary

Based on the presentations and discussions at the AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Arctic Ecosystems and Ecosystem Services, a number of priority research needs were identified.

More detailed understanding of the main large-scale features of Arctic Ocean circulation at various depth layers is needed to develop better conceptual models linking the Arctic cryosphere and hydrosphere so that climate-related changes can be anticipated. The most prominent changes in the cryosphere are anticipated to occur in the seasonal ice zone. Given the scale and implications of these climate-related changes, there is a need for ***multidisciplinary, decadal-long research programs in the seasonal ice zone***, where the challenges are greatest. An interdisciplinary focus on the seasonal ice zone should investigate physical-biological interactions, ecosystem characteristics including timing and productivity, acidification and contaminants. These studies could be conducted on specific sectors of the Arctic and later integrated on a pan-Arctic basis. This requires the support of many countries and organizations in the Northern Hemisphere to respond to the scale of the challenge. Concentrating research on the seasonal ice zone is important because this zone includes the ice edge and the shelf area, which support fisheries and contain other important resources. Innovation and the development of new technologies to study these remote areas are also important.

***Process studies*** are extremely important. They provide quantitative understanding of the mechanisms controlling climate variability and change as well as the observations needed to improve models. Multiple process studies are required to determine how variations in one process influence other processes. Combined and integrated process studies are essentially two or more studies that are co-located and contemporaneous and can provide multivariate data sets with sufficient information for the parameterization or validation of models or remote data products. These studies include processes that impact both natural and social science components. An important goal of future studies in the Arctic should be to identify, characterize, and model both the positive and the negative feedbacks in the Earth-Ocean system.

There is a lack of data on ***Arctic marine ecosystems***, and few data for fish in the Arctic Ocean; it is crucial that such data be collected before fisheries begin in this area. For predicting the potential impact of climate change on Arctic marine ecosystems and their biological communities, a better understanding of regional heterogeneity in the Arctic is needed, as climate-warming effects will vary depending on such features as hydrography, bathymetry, productivity and biodiversity. Information is needed to determine the sensitivities of species and whole communities to climate-related perturbations such as temperature increase. Factors controlling or limiting primary production in the Arctic Ocean are poorly known and are very important for climate projections.

A key research need is to develop ***conceptual frameworks of how Arctic ecosystems could evolve*** in the coming years. Developing an integrated conceptual model of the changes anticipated in productivity, trophic structure and biodiversity of Arctic ecosystems by the ongoing exposure of the Arctic Ocean is a pressing need. This could provide the structure for coordinating interdisciplinary research and setting priorities. Research should be directed at documenting the changes in ecosystem components (from microbes to top predators) in as comprehensive a manner as possible.

Development is needed of ***new technologies***, such as new camera systems for digital photography, a new generation of autonomous underwater vehicles (e.g., gliders), further development of underwater microscopes and new sensors to analyze water-soluble constituents *in situ*. To address the need for broader geographical coverage, technologies need to be developed to characterize select properties over broader areas; they could include remote observatories, floats, buoys, remotely operated vehicles (ROVs), gliders or drones. Increased use of unmanned aircraft systems is also needed.

***Coordinated measurements are needed of key properties and processes*** in representative areas of Arctic shelves and basins. Among important research needs are improved remotely operated observatories, targeted long-duration time series studies of primary and secondary production and the cycling of bioactive compounds, and the development of coupled biogeochemical models that use Arctic-appropriate parameterizations.

There is need to establish a more ***comprehensive all-year network of monitoring stations*** in the Arctic Ocean as well as deployment of drifting and moored platforms in both the surface and deeper waters. This could provide needed seasonal and long-term observations. Furthermore, temporally appropriate time series studies of key components during the 'polar night' are needed. Multiyear time series sites should be established with state and process measurements to gather these data. This requires the development of new technologies that could deliver potentially useful information during the polar night.

Additional research needs include:

- Investigation of the effects of increasing amounts of freshwater in Arctic Ocean surface waters on, for example, circulation.
- Investigation of the effects of Arctic Ocean acidification on marine organisms.
- Analysis of species composition and fish stocks in the marine areas currently accessible, both pelagic and benthic, as a basis for long-term monitoring programs for key species and ecosystems.
- Screening for new chemicals arriving in the Arctic via long-range transport.
- Studies of the distribution and effects of plastics and microplastics in Arctic ecosystems.
- Synthesizing historical baseline information to better understand how climate-related environmental shifts will influence ecosystem structure and function in the future.

# B1 Background

Arctic marine ecosystems are experiencing rapid change, primarily as a consequence of the rapidly changing climate. The sea-ice cover is decreasing rapidly, surface water temperatures are increasing and increased absorption of atmospheric carbon dioxide is causing ocean acidification. Increasing human activities in the Arctic are also influencing the marine ecosystems.

The Arctic Monitoring and Assessment Programme (AMAP), as a partner in the Horizon 2020 coordination and support action EU-PolarNet, is responsible for promoting trans-Atlantic research activities between EU countries and the USA and Canada and, as one aspect of this, to hold international stakeholder workshops to determine common research needs that can be provided as input to the central EU-PolarNet requirement, namely, to develop an Integrated European Polar Research Programme together with an implementation plan. An important aspect of EU-PolarNet is 'connecting science with society', under which dialogue and cooperation with relevant Arctic stakeholders will ensure their input to the formulation of this research program. The AMAP / EU-PolarNet Stakeholder Workshop on Research Needs on Arctic Ecosystems and Ecosystem Services was the second of four AMAP-organized stakeholder workshops to identify and formulate key Arctic research needs over the five years of the project. The central theme of this workshop was research needs to obtain a better understanding of Arctic marine ecosystems and ecosystem services, especially living marine resources, and the factors that influence their functioning, from oceanographic and biogeochemical processes to the many human uses of this area, including fisheries and shipping, in the light of the many changes occurring in the Arctic associated with climate change.

The stakeholder workshop was held in association with the Annual Science Conference (ASC) of the International Council for the Exploration of the Sea (ICES). ASC Theme Session P on 'Arctic Ecosystem Services: Challenges and Opportunities', held on the morning of 20 September, provided scientific input and research ideas for the stakeholder workshop in the afternoon.

The format of the workshop, after the introductory presentations setting the background and aims, comprised presentations by several experts from around the Circumpolar North on a specific theme followed by discussion by the participants of the ideas presented and identification of research needs requiring further work. The workshop participants, as a group, then considered all material presented to identify key themes and approaches.

# B2 Introduction

Representatives of the two co-sponsors of the workshop, AMAP and EU-PolarNet, provided the overall background for the workshop.

Lars-Otto Reiersen, AMAP Executive Secretary, welcomed the participants to the workshop. He noted the significance of this workshop to identify research needs relating to the Arctic marine environment and ecosystems and ecosystem services that can be provided to the European Commission in relation to their funding activities. The results should also be useful to AMAP, ICES and others coordinating or conducting international or national investigations in the Arctic.

Dr. Nicole Biebow, Project Manager of EU-PolarNet, presented a brief overview of this activity. She stated that polar issues have been rising up the political agenda across Europe over the past decade because the rapid changes occurring in the polar regions are significantly influencing global climate with consequences for global society. As a result, the European Union and its executive body, the European Commission (EC), attribute an increasing importance to science and innovation in the high latitudes for a variety of reasons. As a first step, the EC launched a five-year coordination and support action 'EU-PolarNet – Connecting Science with Society', which will work in close cooperation with the EC during these five years to shape Europe's polar research and policy agenda. EU-PolarNet is the largest consortium of expertise and infrastructure for polar research, comprising 17 countries represented by 22 of Europe's internationally respected multidisciplinary research institutes. EU-PolarNet is working closely with the EC by providing support and advice on all issues related to the polar regions.

EU-PolarNet is establishing an ongoing dialogue between policymakers, business and industry leaders, local communities and scientists to increase mutual understanding and identify new ways of working that will deliver economic and societal benefits. The results of this dialogue will be brought together in a plan for an Integrated European Research Programme for the Arctic and Antarctic. This will be co-designed with all relevant stakeholders and coordinated with the activities of many other polar research nations beyond Europe, including Canada and the United States, with which consortium partners already have productive links. The AMAP / EU-PolarNet Stakeholder Workshop on Research Needs on Arctic Ecosystems and Ecosystem Services is one important step in obtaining input from researchers and stakeholders for the Integrated European Polar Research Programme. An affiliated partner, the European Polar Board, is supporting the work and will ensure that the legacy of EU-PolarNet will be sustained.

Activities of EU-PolarNet so far include contributing to the finalization of three funding calls under the Horizon 2020 work program for 2016/2017 dedicated to the Arctic. These calls were designed with partners from Canada and the United States as part of the implementation of the Trans-Atlantic Ocean Research Alliance between the EU, Canada and the USA. EU-PolarNet will continue to assist the EC in defining calls for the 2018–2020 H2020 program, which will allocate a significant amount of funding to Arctic and Antarctic research.

Publicly available deliverables of the project so far include a report on prioritized objectives in polar research (D2.1), a catalogue of all existing European polar infrastructure (D3.2), and an inventory of existing polar monitoring and modelling programs (D2.3). Current priority work includes a process to develop about six white papers addressing urgent polar research questions. These white papers will be developed jointly by stakeholders and scientific experts using a 'Dahlem conference methodology'. Further information can be found on http://www.eu-polarnet.eu/.

The workshop organizer and meeting rapporteur, Janet Pawlak, AMAP Deputy Executive Secretary, emphasized the importance of this workshop as one of the stakeholder contributions to the further development of prioritized objectives for Arctic research and ultimately the Integrated

European Research Programme for the Arctic. As Arctic marine ecosystems and ecosystem services is only one of many research topics for the Arctic, this workshop should aim to identify the most important research needs on this topic. These research needs will be included in the report that she will prepare based on the presentations and discussions at the workshop for submission to EU-PolarNet as a stakeholder contribution on Arctic marine ecosystems and ecosystem services. The report is also a project deliverable to the EC for its information and use.

## B3 Summary of research needs from Theme Session P: Arctic Ecosystem Services: Challenges and Opportunities

Candace Nachman, National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service, USA, Co-Chair of Theme Session P, provided an overview of research needs identified in the presentations and discussions at the session. For predicting the potential impact of climate change on Arctic marine ecosystems and their biological communities, a better understanding of regional heterogeneity in the Arctic is needed, as climate-warming effects will vary depending on such features as hydrography, bathymetry, productivity and biodiversity, for which better data are needed in many parts of the Arctic Ocean and its regional seas. Information is needed to determine the sensitivities of species and whole communities to climate-related perturbations such as temperature increase, as different species have different temperature sensitivities and optima for growth and thus will respond differently to climate change. An understanding of the resilience of whole communities to invasive species is also needed, and this will vary according to regional conditions. Data are lacking on the effects of ocean acidification in the Arctic marine environment, where acidification is occurring more rapidly owing to the cold waters.

With the opening of the Arctic to more human activities, particularly oil and gas installations and shipping, there is a need to develop risk assessment models and management tools to predict potential impacts of oil leaks and spills on fish species in the various Arctic regions. This should also include risks in relation to the introduction of invasive species from the increase in shipping activities.

A lack of data on Arctic marine ecosystems is a major issue. In some regions there are few data for the region or for an important resource; for others, data may exist but they have not been digitized or are not available. In particular, there are few to no data for fish in the Arctic Ocean; it is crucial that such data be collected before fisheries begin in this area.

## B4 Research needs on climate-related changes in the Arctic Ocean and cryosphere

Paul Wassmann, professor of marine ecology at UiT – The Arctic University of Norway, Tromsø, stated that nowhere on earth is climate change more conspicuous than in the seasonal ice zone that surrounds the core pack ice of the Arctic Ocean. Over the course of a year, the seasonal ice zone shrinks with the growing extent of sea ice during winter and expands greatly during spring and summer as the ice cover melts. At present, the seasonal ice zone comprises two-thirds of the total Arctic Ocean area, with an increasing trend of 2% per year. Simultaneously, more than 70% of the total sea ice volume has already melted, the melt season has increased by one month, the ice moves more rapidly and, as the average thickness is now less than 1 m, trans-Arctic transport by ships becomes more realistic. These extreme changes in the Arctic cryosphere and its ecosystems create extraordinary demands on the marine biota. The extent of the changes and the speed of change are outside the 'empirical window'; there are no historical analogues, making it impossible to predict future states of these extremely changing ecosystems. Ecosystem models only have predictive power when the system is close to equilibrium, not when it is outside. Moreover, climate change is accompanied by the development of new industries, new infrastructure and new sources of pollution, the cumulative effects of which are extremely difficult to predict. Nonetheless, sustainable management of marine ecosystems and resources, the ultimate goal for the five coastal nations on the Arctic Ocean, demands significant research emphasis as it is the only essentially unexploited ocean still available to humanity.

What is so special about the Arctic Ocean? It has only 1% of the world ocean volume, but has 25% of the world continental shelf area and 35% of the world's coastline. Twenty of the world's 100 longest rivers flow into the Arctic Ocean, discharging 11% of global river runoff. The Arctic region contains only 0.05% of the global population, but 15% of global petroleum production, 22% of estimated undiscovered petroleum and many metal and non-metal resources. Arctic shelf regions support some of richest global fisheries. Norway alone produces about 15 million fish servings per day from the Barents Sea, which provides about seven wild fish meals per European citizen per year.

The Arctic seasonal ice zone is very dynamic owing to rapid changes in sea-ice conditions. Depending on such factors as wind direction and ocean currents, it may consist of anything from isolated, small and large ice floes drifting over a large area to a compact edge of small ice floes pressed together in the form of solid pack ice. The seasonal ice zone supports many vulnerable environmental processes, and it currently occupies a geographical area as large as Europe (Figure B1). It is the strongest indicator of climate change, but little attention is being given to it because so few people live in the Arctic.

The research needs on climate-related changes in the Arctic Ocean and cryosphere are manifold, not least because the ocean with the world's greatest climate change is also humanity's least-known ocean. In addition to the generic credo of 'more research is needed', what are the particular research challenges to manage the Arctic Ocean in a sustainable manner? An evaluation of the research needs on climate-related changes in the Arctic Ocean and cryosphere requires that we see the proportions of the problem correctly and that we evaluate them together with the needs of humanity in an objective manner. In this regard, it is clear that the loss of Arctic sea ice has emerged as the leading signal of global warming. The sea-ice extent in summer has decreased dramatically together with a great loss of multi-year ice; ice loss is exacerbated by an increase in drift speed of sea ice and a longer melt season. Overall, there has been a loss of about 75% of ice volume in the past three decades.


Figure B1 Changes in the summer seasonal ice zone in the Arctic.

The circulation in the Arctic Ocean is influenced by circulation patterns in the Pacific and Atlantic Oceans. While there is a general understanding of the principal large-scale features of Arctic Ocean circulation at various depth layers, many details are missing. This understanding is needed to develop better conceptual models linking the Arctic cryosphere and hydrosphere so that climate-related changes can be anticipated. The most prominent changes in the cryosphere now and in the decades to come are anticipated to occur in the seasonal ice zone. These changes include changes in the extent and thickness of the sea-ice cover and changes in the melt season, with associated changes in seawater stratification, nutrient levels and availability, and the composition of biota. An interdisciplinary focus on the seasonal ice zone should investigate physical-biological interactions, ecosystem characteristics including timing and productivity, acidification and contaminants. These studies could be conducted on specific sectors of the Arctic and later integrated on a pan-Arctic basis.

The seasonal ice zone has an importance beyond the Arctic. The location and duration of the seasonal ice zone affects shipping through this region, fisheries, oil and gas exploration, and minerals extraction. The atmospheric and oceanographic conditions of the seasonal ice zone also influence weather variability down to 30° to 40°N.

Research needs regarding the influence of changes in the cryosphere on the seasonal ice zone include:

- Estimating the influence of Arctic amplification on the atmospheric uptake of carbon dioxide in the seasonal ice zone.
- Projecting changes in fisheries, both fish species and abundances, in the seasonal ice zone.
- Projecting changes in the biodiversity of the seasonal ice zone.

Other research needs regarding the Arctic cryosphere include investigations of the implications of the melting of the Greenland ice sheet in relation to increased ocean stratification, carbon dioxide uptake, biological production and mid-latitude weather. Implications of permafrost thaw on bacterial breakdown of organic matter in the Arctic Ocean also need investigation.

Given the scale and implications of these climate-related changes, there is a need for multidisciplinary, decadal-long research programs in the seasonal ice zone, where the challenges are greatest. This requires the support of many countries and organizations in the Northern Hemisphere to respond to the scale of the challenge. Sustainable development of the Arctic Ocean demands knowledge-based ecosystem and resource management, and currently this knowledge is inadequate.

In the discussion of this presentation, it was considered that given the importance of the seasonal ice zone for the whole world, there is a need to better understand and better articulate these connections and the importance of this area to a broader public. People living outside of the Arctic are not aware of how climate change in the Arctic may affect them. Many political decisions are based on industry needs, not on peoples' needs; the loss of sea ice in the Arctic benefits industry very much. Politicians appreciate these economic opportunities, without being aware of the negative aspects of the enormous influence of climate change on Arctic ecosystems. Political reasons have also resulted in the greatest amount of U.S. research funding going to the Antarctic, with considerably less allocated to the Arctic.

On the positive side, however, the United States has closed all fisheries in the Arctic because the knowledge base for fisheries regulations does not exist at this time. Furthermore, Norway has the only system of knowledge-based ecosystem management, whereby there is a need to be able to determine risks to the ecosystem and permission is required from parliament for commercial activities to be conducted in the Arctic.

## B5 Research needs for Arctic ecosystems and biodiversity

Victor Smetacek, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, stated that the ongoing retreat of Arctic summer sea-ice extent is a tragic reality that should, nevertheless, be seized upon by the scientific community and used as a heaven-sent (literally) opportunity to address questions that could not have been addressed otherwise: it is an ocean-scale colonization experiment. Massive, extensive phytoplankton blooms have already been observed under the melting sea-ice cover. Spring and autumn blooms typical of temperate regions are also already appearing in open waters of the Arctic Ocean. Northward migration of some species, including a key diatom (*Neodenticula seminae*) and zooplankton species (copepods and amphipods), has also been reported, all indicating that colonization of the opening pelagic habitat is already occurring. This calls for efforts to coordinate international research activity on the scale of a giant experiment.

Because the questions pertain to all fields of marine science, developing an integrated conceptual model of the changes anticipated in productivity, trophic structure and biodiversity of Arctic ecosystems by the ongoing exposure of the Arctic Ocean is a current pressing need. This could provide the structure for coordinating interdisciplinary research and setting priorities. Baselines have been established by cruises that ventured into the multi-year ice fields before 2007. Research should now be directed at documenting the changes in ecosystem components (from microbes to top predators) in as comprehensive a manner as possible. The changes will be manifested in successive shifts in annual cycles in the course of the coming years. Following the sequence of events in the plankton and benthos will provide new insights into the functioning of marine ecosystems and enable the formulation of hypotheses that could be successively tested as the new ecosystems develop.

Traditionally, colonization experiments have been carried out by terrestrial and benthic ecologists to identify pioneer species and the stages in maturity undergone by the affected ecosystems. They also offer the opportunity to assess the impacts of bottom-up and top-down factors in shaping ecosystem structure and functioning. This is the first time that this opportunity is being offered at an oceanic scale to pelagic scientists, and by extension, also to fisheries biologists and benthologists. The response of indigenous species to the Great Exposure (or call it Illumination) and their interaction with boreal invasive species, introduced from the Pacific and Atlantic Oceans, will shed light on temperature adaptations, dispersal ability and many other organism properties. The first and foremost research need is to overcome disciplinary boundaries by developing conceptual frameworks of how Arctic ecosystems could develop in the coming years. This can be achieved by holding brainstorming workshops with specified goals. Encouragement could come from funding agencies for integrated proposals in which over-arching hypotheses are investigated. Other associated activities could include the identification of sensitive regions that could be designated as marine protected areas.

The development of new technologies, such as new camera systems to study and quantify plankton *in situ*, could also be supported. A sizeable part of the human brain is devoted to processing visual information, but so far we have only seen what instruments of our making show us: the history of advances in marine sciences is a history of the development of methodology and instruments (our extended sense organs). Seeing is believing, but the marine scientific community so far has had to believe without seeing. No one has observed functioning pelagic ecosystems the way terrestrial ecologists can examine their systems; experiments with plankton carried out *in vitro* have proved to be of limited application. However, the perspectives opened by digital photography and the new generation of autonomous underwater vehicles (e.g., gliders) are enormous: the application of recently developed underwater microscopes will literally open new vistas for our brains to work with. It is time to enhance our efforts to study pelagic organisms *in situ*, to accompany and enhance the information coming from omics studies.

The new era of visualization described here will prove invaluable for fostering interdisciplinary cooperation as it will make marine biota accessible to all. Optically arresting images and videos that convey the feeling of declining Reynold's numbers on the performance of the organisms, from whales to microbes in the water column and benthos, will lead to eye-opening insights for scientists that can even be shared directly with the public. The effect on the latter in terms of understanding the issues at stake, at a time when marine ecosystems are becoming more vulnerable to industrial-scale exploitation, cannot be overemphasized. We owe it to the less charismatic biota – the workhorses of the oceans regulating our climate – to place them in the limelight that they deserve.

In the discussion of this presentation, the issue of visualization was considered important. More technical development and coordination is needed to produce appropriate means to visualize processes in the marine ecosystem. The U.S. NOAA is experimenting with unmanned observation systems; however, this requires a considerable amount of resources and work as well as partnering, particularly with industry.

Another issue is that most decisions affecting the Arctic are made by people who have never visited the Arctic. Given that scientists must fight for every data point they receive, education of the public so that they elect politicians who will support work in the Arctic is important. There is now a movement in some countries, for example, Norway, to sponsor annual visits to the Arctic for small groups of people so that they gain a better understanding of the conditions and greater empathy for Arctic issues. In Canada, a recent two-week cruise on an icebreaker was held for interested people who could afford the high cost. A public event, 'Arctic Matters Day', was held in the U.S. earlier in the year to provide visualization on why the Arctic matters to everyone; similarly, the U.S. Department of State initiated a project where representatives from all 50 states wrote about what the Arctic meant to them to highlight the U.S. chairmanship of the Arctic Council (April 2015 to May 2017).

It was noted that innovation is now required as part of EU-funded projects; proposals need to indicate societal relevance, particularly job creation, as well as innovations that will result from the project. In general, there is a greater pressure for scientists to take social scientists into their work.

## B6 Need for monitoring in Arctic Ocean: contaminants, climate, acidification

Lars-Otto Reiersen, AMAP Executive Secretary, stated that AMAP had been established in 1991 with a mandate to monitor and assess the state of the Arctic environment with respect to pollution and climate issues, including effects on ecosystems and humans. In this connection, AMAP defined an 'ideal' monitoring program including atmospheric, terrestrial, freshwater, marine and human health sub-components to gather the necessary information needed to perform scientific assessments of levels, trends and effects of contaminants, and of climate change and ocean acidification. The results of these assessments are used to provide science-based policy-relevant information.

The AMAP monitoring program is implemented largely through ongoing national monitoring and research activities in the eight Arctic countries, and to varying degrees. This reflects the fact that, although the program identifies 'essential' and 'recommended' measurements, there are no mandatory requirements for implementation. In this respect, AMAP/Arctic Council differs from other arrangements and organizations such as the OSPAR Commission and the Helsinki Commission that have Conventions with a legally binding status. Notwithstanding this, monitoring and research efforts by Arctic and non-Arctic countries and their institutions – both agencies and universities – have allowed AMAP over the years to produce a number of high-quality scientific assessments.

AMAP marine monitoring activities over the past 25 years have confronted a number of challenges regarding different aspects of marine monitoring and observations, equipment, sensors, data handling, etc., as well as the research needs to achieve a better coverage of the Arctic Ocean and its adjacent seas.

AMAP is also a large consumer of data from many sources. Although short-term research programs are major sources of data, satellites have provided valuable information about sea-ice extent for more than three decades and ice-tethered profilers have collected data on such properties as temperature, salinity and dissolved oxygen and carbon dioxide in Arctic seawater for the past decade. Under the GEOTRACES program, marine biogeochemical cycles of trace elements and their isotopes are being studied in the Arctic Ocean, among other marine areas. Russia has operated drifting ice stations, but many have now melted away; aside from that, most Russian monitoring stations are on land, with little monitoring activity in the Arctic Ocean. However, a Russian institute recently cooperated with a Norwegian institute in extensive surveys of the Barents Sea, comprising hydrographic and plankton stations as well as bottom and pelagic trawl stations. Norway has conducted cruise surveys in the Barents Sea for over one hundred years, studying oceanographic conditions, plankton and other marine properties.

Ocean acidification is being studied in many areas of the Arctic Ocean, with particularly intensive monitoring in the Greenland Sea and the Barents Sea. The abundance of commercial species of fish in these two regional seas is also heavily monitored. Other monitoring programs include monitoring of nutrient concentrations in coastal waters of parts of the Canadian Arctic as well as a program to monitor marine mammals at many locations in the Canadian Arctic.

The monitoring of concentrations of environmental contaminants in marine biota, including shellfish, fish, marine birds and marine mammals, is being conducted regularly in most Arctic countries, but the number of samples is small and the geographic distribution is sparse.

The use of new instrumentation to study the conditions in the Arctic is very important. AMAP has developed guidelines for the use of unmanned aircraft systems (UAS) for the collection of scientific data in the Arctic.

Given the rapidity of climate change in the Arctic there are needs for:

- Establishment of a more comprehensive all-year network of monitoring stations in the Arctic Ocean.
- Deployment of drifting and moored platforms at both the surface and in deeper waters.
- Increased use of unmanned aircraft systems.
- Development of new sensors to analyze water-soluble constituents in situ.
- Development of new models to elucidate combined effects of climate change, contaminants and other stressors in the Arctic and adjacent seas.

Research is needed to:

- Investigate the effects of increased temperatures on Arctic marine species.
- Investigate the effects of increasing amounts of freshwater in Arctic Ocean surface waters on, for example, circulation.
- Investigate the effects of Arctic Ocean acidification on marine organisms.
- Analyze species composition and fish stocks in the marine areas currently accessible, both pelagic and benthic, and prepare long-term monitoring programs for key species and ecosystems.
- Screen for new chemicals arriving in the Arctic via long-range transport.

In the discussion, it was noted that there are very few data for the Central Arctic Ocean and, with the aging of research vessels operating in the Arctic, it was difficult to know how information on this area will be obtained. On the other hand, concentrating research on the seasonal ice zone is clearly important because this zone includes the ice edge and the shelf area, which are much more interesting to national funding agencies given the fisheries and other resources in this area. Emphasis on innovation and the development of new technologies to study these remote areas was also considered important.

## B7 Needs for interdisciplinary Arctic state and process studies

Richard Rivkin, Professor in the Department of Ocean Sciences, Memorial University, Newfoundland, emphasized the need for interdisciplinary state and process studies in the Arctic. The Arctic Ocean is a relatively shallow Mediterranean sea, surrounded by land, receiving more than 10% of global freshwater discharge and containing about 1% of the ocean volume and about 4% of the ocean area. It is cold, highly stratified and large areas are both seasonally ice covered and dark. These conditions create both research challenges and opportunities.

The hydrography, ecology and biogeochemistry of the Arctic Ocean are unique and the outflows are important drivers for global circulation, heat flux and climate. The Arctic is experiencing extreme global warming that is leading to a reduction in ice cover with concomitant changes in circulation patterns, seawater chemistry, vertical mixing, primary and secondary production and a greater ease of access by invasive species, including human tourists. Although the Arctic has been studied during scientific research expeditions since the 1800s, there are large gaps in our understanding of the distribution and control of the main ecosystem components, and of the factors controlling the seasonal cycles of important biological, chemical and biogeochemical processes, especially those occurring during the dark boreal winter. Thus, process studies are extremely important. Process studies provide quantitative understanding of the mechanisms controlling climate variability and change and they provide the observations needed to improve models. Multiple process studies are required to determine how variations in one process influence other processes. Combined and integrated process studies are essentially two or more studies that are co-located and contemporaneous and can provide multivariate data sets with sufficient information for the parameterization or validation of models or remote data products. Field programs in the Arctic are by nature interdisciplinary and include processes that impact both natural and social science components.

Earth systems interact through both linear and non-linear processes that can vary on different spatial and temporal scales. Focused studies of key processes underpinning the Earth's climate system are critical to obtain an understanding of the ocean's role in climate dynamics and potential feedbacks. An important goal of future studies in the Arctic should be to identify, characterize and model both the positive and the negative feedbacks in the Earth-Ocean system.

One of the issues inherent in multidisciplinary process studies is that of scale. Multiple spatial and temporal scales characterize an individual disciplinary science and its applications. This is matched by an equally broad range of spatial and temporal scales when comparing disciplines (Figure B2). This requires that research questions be developed both around trans-disciplinarity and at multiscale perspectives to understand the current and future states of the Arctic. There is also now a need to include social science components in large research projects.

A good starting point for the development of research questions is to determine what we know already and, from that, what do we know that we do not know. In other words, to identify what are the process uncertainties, we need to know the current state of knowledge in the field. In terms of the Arctic, we know that the open water area in the Arctic Ocean increased significantly (25–27%) between 1998 and 2012. Over this same period, annual net primary production increased about 30%, with the largest increases occurring on the interior shelves and smaller increases on inflow shelves; outflow shelves experienced a net decrease. Increased annual net primary production was often associated with reduced sea-ice extent and a longer phytoplankton growing season. However, there are many uncertainties associated with these estimates of primary production and with the consequences of observed changes. Among other questions, there is uncertainty concerning the contributions of open-water, under-ice and bottom-ice primary production. Factors controlling or limiting primary production in the Arctic Ocean are not known, and if it is the nutrient supply that is limiting, the question is whether production is sustained on new or regenerated nutrients. Major questions include: What is the composition of the phytoplankton community? Is there downward export and sequestration of organic matter? Is there export from the food web, or is there retention or remineralization? Answers to these three questions have major consequences for climate projections.

To begin to predict future environmental conditions in the Arctic, a full understanding of the past is needed. The Arctic Ocean is changing rapidly. To have a complete understanding of how these environmental shifts will influence ecosystem structure and function in the future, it is critical to synthesize historical baseline information.

Much baseline information still needs to be collected on a broad basis in the Arctic. The Arctic Ocean is very heterogeneous, with about half of the area occupied by shelves whose physical, chemical and biochemical characteristics appear to differ. Furthermore, past observations are discontinuous in both space and time. To address this need for broader geographical coverage, new technologies need to be developed and used to characterize select properties over broader areas. These technologies could include remote observatories, floats, buoys, ROVs, gliders or drones. Coordinated measurements are needed of key properties and processes in representative areas of Arctic shelves and basins.

Seasonal and long-term observations are also needed. Early studies suggested that ice-covered areas were unproductive, with

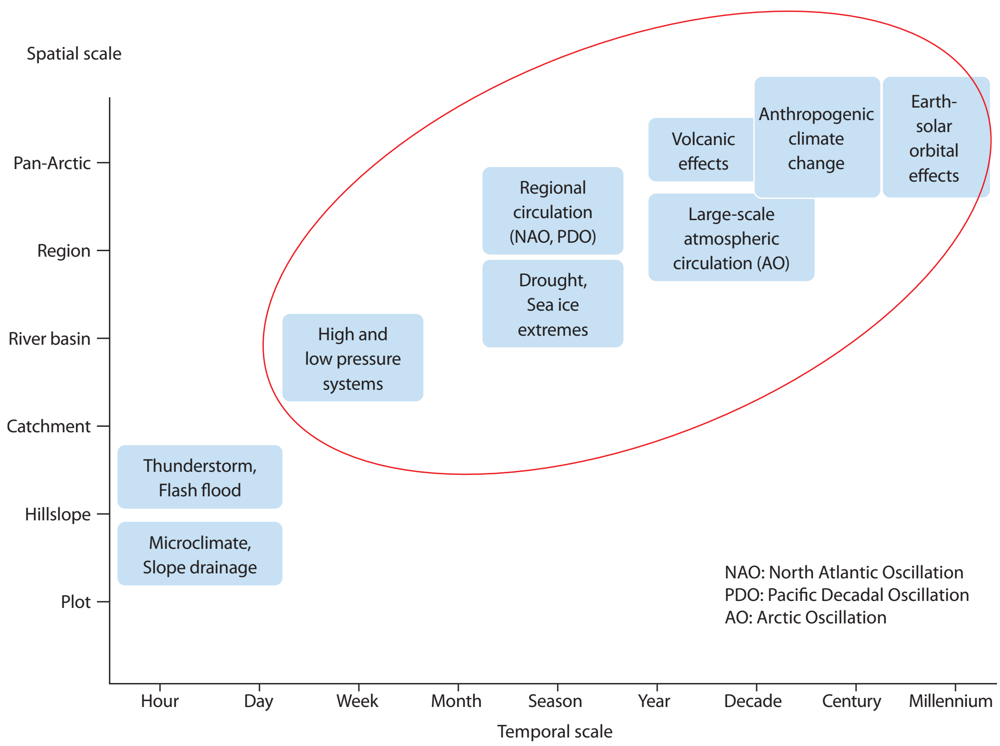


Figure B2 Spatial and temporal scales related to weather and climate dynamics. The red line groups the multiscale perspectives around which research questions need to be developed to understand current and future states of the Arctic. Source: U.S. Arctic Research Commission.

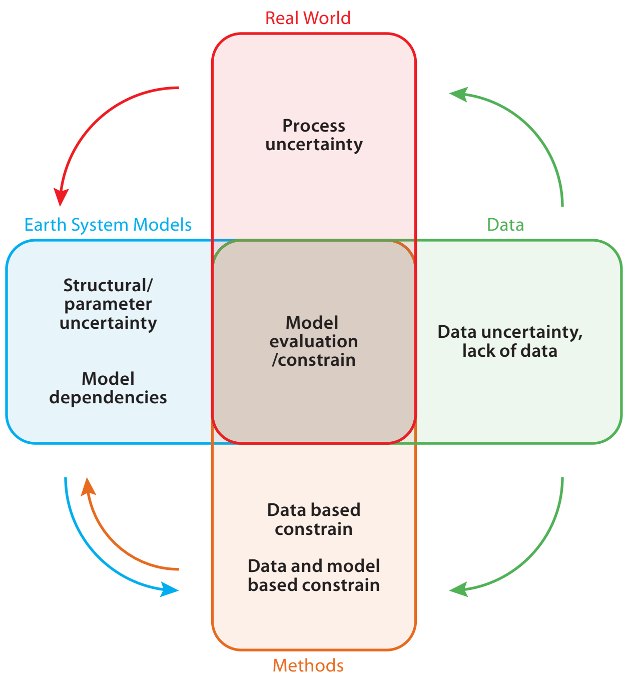


Figure B3 Possible conceptual approach to integrate process studies for future Arctic research needs. Source: Dalmonech et al. (2014).

long periods of zero productivity. However, it has now been shown that the 'Arctic winter' and 'polar night' are key periods during which ecologically important processes mediated by metazoa and biogeochemically mediated transformations by heterotrophic microbes take place. It is critically important to obtain temporally appropriate time series studies of key components during the 'polar night'. Multiyear time series sites need to be established with state and process measurements to gather these data. This requires the development of new technologies, such as perhaps satellite products in addition to ocean color that could deliver potentially useful information during the polar night. Remote observatories would be useful as well as determining potential proxies for the information needed.

Thus, there is a strong need for coordinated research in the Arctic, as well as a compiled summary of historical and the best current information. This can be used to determine critical data needs and a hierarchical assessment of what information will provide the most or best incremental information per unit effort or cost. Data uncertainties need to be evaluated and model outputs assessed (Figure B3). Among the important research needs for future Arctic studies are improved remotely operated observatories, targeted long-duration time series studies of the primary and secondary production, and the cycling of bioactive compounds, and the development of coupled biogeochemical models that use Arctic-appropriate parameterizations.

## B8 New research challenge: Litter/plastics in the Arctic marine environment

Tina Schoolmeester, GRID-Arendal, a Norwegian non-profit foundation that works with the United Nations Environment Programme and other agencies to support environmental decision-making and raise awareness, stated that marine plastic pollution is a worldwide problem. Of the approximately six billion tonnes of plastic produced since the 1950s, it is estimated that between 86 and 150 million tonnes of plastics have ended up in the sea (Fabres et al., 2016). Between 50% and 90% of litter in the ocean is plastics or microplastics (<5mm).

Plastics are durable and quickly redistributed by ocean currents between the different regions of the global ocean. This means that plastic pollution originating elsewhere has also ended up in polar waters. It has been estimated that between 16,200 tonnes and 1.9 million tonnes of plastic are imported annually to the Arctic from the North Atlantic and the Bering Sea (Zarfl and Matthies, 2010). Recent research has already identified the occurrence of plastic pollution in all Arctic marine reservoirs, namely coastal areas, sea surface waters, the water column, the sea floor and, very important in the light of climate change, within sea ice.

Because Arctic coastal areas are sparsely populated and human activities at sea are still limited, the potential local contribution of plastic debris and microplastics is relatively small compared to other areas. However, very little is known regarding input from rivers flowing directly into the Arctic. Large rivers flowing into the Arctic, particularly some of the large Russian rivers, originate in populated areas and carry litter and plastics to the Arctic, littering the shores of Siberia. Forecasted increases in human activities, particularly maritime activities such as shipping and fisheries, in the Arctic Ocean could change the relative importance of local sources.

Currently there is a wide variation in estimates of the amount of plastics transported to the Arctic. Both the quantitative and qualitative data are too sparse to obtain an overall understanding of total amounts, concentrations and transport paths of plastics into and within the Arctic. This warrants further research efforts in order to identify the potential impact on organisms.

While the overall impact of plastic debris on Arctic biota remains uncertain, available studies clearly confirm that a plastic diet does not contribute to healthy marine organisms and ecosystems. The ingestion of macroplastics results in poor nutrition, mechanical damage to the stomach, and a decline in health and even death, including by entanglement in marine plastic debris. Even less is known about the effects of microplastic ingestion; however, owing to the ubiquitous presence of microplastics, they can be potentially ingested by a broad range of organisms from zooplankton at the base of the food chain, all the way to commercial species and apex predators such as seabirds and marine mammals. The impact of ingestion can be mechanical and/or chemical through the potential bioaccumulation of the toxic substances associated with plastic, such as phthalates, polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs) and styrenes. In addition to ingestion, plastic debris can affect organisms through entanglement, serve as vectors for the dispersion of invasive species, and smother habitats in accumulation hot spots.

The fragmented and discontinuous nature of the available knowledge does not allow a clear enough assessment of either the global or the Arctic-specific impacts of marine plastics. Further research is needed to identify and quantify local Arctic sources (both land- and sea-based) and fluxes through the various input pathways, as well as to quantify oceanic input from outside the Arctic. There is a need to determine the amounts and concentrations of plastics and microplastics in Arctic surface waters, the water column, sea ice and seabed sediments as well as to understand the relationship between sources and sinks to identify areas vulnerable to accumulation. A better understanding is also needed of the uptake into biota.

Regarding impacts, there is a need for investigation of the impacts of plastics and microplastics at the species and population levels of organisms in the Arctic. This should include both mechanical impacts from ingestion and entanglement, as well as chemical impacts from ingestion and the bioaccumulation of toxic substances within or adsorbed to the plastics and possible consequences for human health of consumption of affected biota. Furthermore, there is a need to understand the mechanisms of plastic as vectors for inputs of pollutants and invasive species into the Arctic.

The effect of the colder Arctic climate on plastic degradation also needs better study.

Finally, government frameworks for prevention, remediation and adaptation strategies and policies should be urgently designed to address the already identified sources and pathways in order to guarantee healthy Arctic marine ecosystems and the services that they provide.

## B9 Panel discussion of research needs related to Arctic marine ecosystems and ecosystem services

To start off the panel discussion, Anne Hollowed, NOAA National Marine Fisheries Service (NOAA Fisheries), Alaska Fisheries Science Center in Seattle, described the NOAA Fisheries Climate Science Strategy, which was adopted to strengthen the underlying science regarding climate-related impacts on marine and coastal ecosystems and their influence on fisheries. The objectives of this strategy are to build and maintain an adequate science structure, track changes and provide early warnings, understand the mechanisms of change, project future conditions, develop adaptive management strategies as well as robust management strategies, and ultimately create climate-informed biological reference points for use in fisheries management. Regional action plans have been prepared under this strategy, including one for the southeast Bering Sea. Integrated interdisciplinary research teams have been established to implement the action plans, using both remote and *in situ* monitoring and modelling in relation to a core suite of ecosystem observations and indicators, with the aim of making six- to nine-month projections of the climate to use for fisheries predictions. Work is also being conducted to determine ecosystem thresholds for management actions.

In the discussion, it was stressed that there is a need to do considerably more monitoring of the conditions in the Arctic Ocean. However, the question was raised as to why monitoring of fisheries should be considered so important when fish do not constitute a large component of that ecosystem. The view was expressed that monitoring the biogeochemistry of the Arctic Ocean and its regional seas was the most important at this stage, as the role of marine mammals, fish and complex metazoa is relatively small in terms of biogeochemical changes. This reflects the concern that a tipping point has been passed in the ocean with regard to atmospheric $CO_2$. Even if the production of $CO_2$ is stopped, the ocean will start outgassing rather than absorbing $CO_2$, raising the question of how changes in the ocean can be managed if this tipping point has been passed. This also has an influence on the balance between remediation and adaptation.

Nonetheless, fisheries clearly provide an ecosystem service and thus fisheries monitoring is important. Additionally, although fisheries do not affect the $CO_2$ balance in the ocean, given that fisheries will be seriously affected under RCP8.5[1], the value of fisheries resources could be used to enhance global acceptance of limiting greenhouse gas emissions. Furthermore, with less sea ice, there may be more fish in the Arctic Ocean, although it is not known which species would be enhanced. Predicting these changes requires the development of representative fisheries scenarios.

It was further noted that the management of fisheries on the high seas is very poor. As there is yet little fishing in the Arctic Ocean itself, there is the possibility that a better management structure could be developed now so that when there are more fish a good management structure will already exist.

Fishing should not be allowed in ice-dependent ecosystems until a clear understanding of these ecosystems and the level of a sustainable harvest has been obtained. An environmentally based concept of sustainability needs to be developed. Given that there is no equivalent of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) in the Arctic, at present there is no institutional basis for cooperative, sustainable fisheries management.

Ecosystem services can be provided at a range of different levels. Carbon sequestration is a major global ecosystem service. Understanding the fate of production is important to knowing climate change impacts in the ocean. However, the area of the Arctic Ocean is relatively small and the amount of nutrients is so small that little carbon sequestration can be anticipated. Furthermore, most macrofauna have been overharvested by humans, leaving microbiology as the most promising to study. Several hundred years ago, coastal areas had a much greater large animal biomass than they do today. Major species have been removed from the system, so we cannot know the original system. This has been witnessed in the Southern Ocean with the influence the loss of whales has had on the krill population.

There is also the issue of biodiversity: large organisms depend on systems that we do not understand. Another issue regarding biodiversity is that we are changing the ways of observing systems and they are not comparable with previous types of observations. We will not have comparable data sets and there is a need to deal with this.

The need for research includes observations and models and both should be linked to parameterization. Attempts should be made to parameterize processes so that they can be applied to

[1] A representative concentration pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) in 2014. A sizeable portion of recent studies on future climate impacts have focused on a warming scenario called 'RCP8.5'. This high-emissions scenario is frequently referred to as 'business as usual', suggesting that is a likely outcome if society does not make concerted efforts to cut greenhouse gas emissions.

broad geographical areas; however, as the temperature regime is different for different areas, the geographically related temperature-dependent response for a species can be different from its seasonal temperature response. A long-term goal is also to downscale global climate models so we can obtain reasonable information on impacts on a smaller geographical scale.

As an example of a regional observation program, a research project has been established in the southeastern Bering Sea and in the Chukchi Sea to determine the variability of production, both the interannual variability and the decadal variability, so that changes arising from climate change can be determined. This monitoring will need to be conducted for a decade for this variability to become evident.

It was noted that making recommendations from the workshop depends on the aims that such research are intended to achieve. Climate change is important for everyone, including what is changing and how it is changing. There is already a lot of research being conducted, so the question is whether there is a need for another incremental effort or do we want to get more than another set of data points. Here we have spoken about interdisciplinary work and conveying the results to the public, to make connections that have not yet been made. There is a need to determine the questions and to pay attention to what has already been done rather than simply starting new studies.

As this workshop is being held to provide research topics to the European Commission, the question was raised as to what are 'hot topics' that could be attractive to politicians. The EC is looking for themes with societal relevance. One topic with societal relevance concerns how the Arctic is influencing mid-latitude weather patterns. If the Arctic is not understood and taken into account, the ability to predict mid-latitude weather is diminished. It is also important to develop communication methods to convey to the general public in a meaningful way the implications and effects of climate change in the Arctic, given that so few have visited an Arctic area.

Other questions and ideas arising in the discussion included the following:

- What can ecosystem research do with regard to COP21[2] targets? How will COP21 influence society?
- How do these changes affect Indigenous peoples who are dependent on local animals for their food supplies?
- How can we develop technologies for people living in the Arctic that they can use to track conditions – community-based monitoring tools? This could include intelligent observations with cameras. Crowd research on the internet could be employed to get people interested.
- Good governance is important to the Arctic.
- Cooperation should be enhanced with Asian countries, particularly China, India, Japan and South Korea all of which are eager to cooperate, in research and monitoring in the Arctic.

## B10 Final remarks

The Co-Chairs Candace Nachman and Susanne Kortsch thanked the speakers and participants for their contributions to the workshop. On behalf of AMAP, Lars-Otto Reiersen expressed his appreciation, noting that much good information had been presented and discussed. From EU-PolarNet, Nicole Biebow stated that the workshop had been very informative, and now the most relevant issues need to be conveyed to the EU-PolarNet consortium.

### References

Dalmonech, D., Foley, A.M., Anav, A., Friedlingstein, P., Friend, A.D., Kidston, M., Willeit, M., and Zaehle, S. 2014. Challenges and opportunities to reduce uncertainty in projections of future atmospheric $CO_2$: a combined marine and terrestrial biosphere perspective. Biogeosciences Discussions, 11:2083-2153.

Fabres, J., Savelli, H., Schoolmeester, T., Rucevska, I., and Baker, E., 2016. UNEP and GRID-Arendal, 2016. Marine Litter Vital Graphics. United Nations Environment Programme and GRID-Arendal.

Zarfl, C. and Matthies, M., 2010. Are marine plastic particles transport vectors for organic pollutants to the Arctic? Marine Pollution Bulletin, 60:1810-1814.

[2] The 2015 United Nations Climate Change Conference, COP21 was held in Paris, France, from 30 November to 12 December 2015.

# AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Arctic Ecosystems and Ecosystem Services

Riga, Latvia, 20 September 2016

## Workshop agenda

### Morning session

International Council for the Exploration of the Sea (ICES) Annual Science Conference
Theme Session P: Arctic Ecosystem Services: Challenges and Opportunities
(Co-sponsored by AMAP, EU-PolarNet and ICES)
*Co-Chairs*: Candace Nachman (USA), Susanne Kortsch (Norway)

### Afternoon session

**AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Arctic Ecosystems and Ecosystem Services**
Co-Chairs: Candace Nachman (USA), Susanne Kortsch (Norway)

**Opening and welcome**
Lars-Otto Reiersen, AMAP Executive Secretary

**Context of the workshop: Research needs defined for EU-PolarNet work**
Nicole Biebow, AWI, Project Manager EU-PolarNet

**Aims and outcome of the workshop**
Janet Pawlak, AMAP Secretariat – Rapporteur

**Summary of research needs from morning session**
Candace Nachman, NOAA National Marine Fisheries Service, USA

**Research needs on climate-related changes in the Arctic Ocean and cryosphere**
Paul Wassmann, University of Tromsø

**Research needs for Arctic ecosystems and biodiversity**
Victor Smetacek, Alfred Wegener Institute

**Need for monitoring in Arctic Ocean: contaminants, climate, acidification**
Lars-Otto Reiersen, AMAP Executive Secretary

**Needs for interdisciplinary Arctic state and process studies**
Richard Rivkin, Memorial University of Newfoundland

**New research challenge: Litter/plastics in the Arctic Marine Environment**
Tina Schoolmeester, GRID Arendal

**Panel discussion – Research needs for Arctic Marine Ecosystems**

**Final remarks and closing of meeting**

# Workshop participants

| Name | Institute |
| --- | --- |
| Nicole Biebow* | Alfred Wegener Institute, Bremerhaven, Germany |
| Wenting Chen | Norwegian Institute for Water Research (NIVA), Norway |
| Louise Copeman | Oregon State University, Corvallis, OR, USA |
| Karen Edelvang | DTU AQUA, Denmark |
| Johan Etourneau | CNRS-INSU, Paris, France |
| Harald Gjøsæter | Institute for Marine Research, Norway |
| Agnes C. Gundersen | Møreforskning Aalesund, Norway |
| Anne Hollowed† | NOAA Fisheries, Alaska Fisheries Science Center, Seattle, WA, USA |
| Daniel Howell | Institute for Marine Research, Norway |
| Henry Huntington | Huntington Consulting, Eagle River, Alaska, USA |
| Susanne Kortsch Co-Chair | UiT – The Arctic University of Norway, Tromsø, Norway |
| Alexandra Kraberg | Alfred-Wegener Institute, Helgoland, Germany |
| Ben Laurel | NOAA Fisheries, Alaska Fisheries Science Center, Newport, OR, USA |
| Candace Nachman ‡ Co-Chair | NOAA National Marine Fisheries Service, USA |
| Janet Pawlak | AMAP Secretariat, Oslo, Norway |
| Lars Ravn-Jonsen | Department of Environment and Business Economies, University of Southern Denmark, Odense, Denmark |
| Lars-Otto Reiersen* | AMAP Secretariat, Oslo, Norway |
| Laura Richards | North Pacific Marine Science Organization (PICES), Sidney, British Columbia, Canada |
| Richard Rivkin* | Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, Canada |
| Tina Schoolmeester* | GRID Arendal, Arendal, Norway |
| Victor Smetacek* | Alfred Wegener Institute, Bremerhaven, Germany |
| Paul Wassmann * | UiT – The Arctic University of Norway, Tromsø, Norway |

* Workshop presenter and panelist; ‡Presenter; †Panelist

# International Council for the Exploration of the Sea (ICES) Annual Science Conference

Theme Session P - Arctic ecosystem services: challenges and opportunities

Conveners: Candace Nachman (USA) and Susanne Kortsch (Norway)

## Presentations

**P:624 Ballast water of domestic ships as a pathway for the introduction of non-indigenous mesozooplankton in coastal Nunavik, Canada**
*Pascal Tremblay, André Rochon, Gesche Winkler, Kimberly Howland, Nathalie Simard, Sarah Bailey*

**P:280 Towards quantitative oil spill risk assessment in the Arctic sea areas**
*Maisa Nevalainen, Inari Helle, Jarno Vanhatalo*

**P:122 An overview of the adequacy of Arctic sea basin data**
*Belinda J. Kater, Martine J. van den Heuvel-Greve, Peter Thijsse, CJ Beegle-Krause, Oscar Bos, Bart Grasmeijer, Le Griffin, Eline van Onselen, Harriet van Overzee, Gerjan Piet, Andrea Sneekes, Arjan Tuijnder, Pepijn de Vries, Jan Tjalling van der Wal*

**P:450 Modelling spatio-temporal variation of surface hydrography in an Arctic shelf sea**
*Jussi Mäkinen, Jarno Vanhatalo*

**P:502 Structure and resilience of the benthic food web across the Canadian Arctic Ocean and the Chukchi Sea**
*Noémie Friscourt, Christian Nozais, Philippe Archambault*

**P:129 Pink Salmon as Sentinels for Climate Change in the Arctic**
*Edward V. Farley, Jr., Wesley Strasburger, Jeanette C. Gann, and Kristin Cieciel*

**P:248 A Bioeconomic Model of Ocean Acidification Challenges in the Baffin Bay/Davis Strait Shrimp Fishery**
*Brooks A. Kaiser, Lars Ravn-Jonsen*

**P:445 Benthic non-indigenous species in ports of the Canadian Arctic: risks associated with global warming and shipping activity**
*Kimberly Howland, Jesica Goldsmit, Philippe Archambault, David Barber, Guillem Chust, George Liu, Jennifer Lukovich, Chris McKindsey, Ernesto Villarino*

**P:647 SYMBIOSES: a practical risk management tool to integrate fisheries and hydrocarbon activities in the Lofotens and Barents Sea, Norway**
*Daniel Howell, JoLynn Caroll, Frode Vikebø*

**P:268 Socio-economic impacts of ocean acidification and warming on Barents Sea Cod**
*Martina H. Stiasny, Martin Hänsel, Catriona Clemmesen, Flemming Dahlke, Felix H. Mittermayer, Martin Quaas, Thorsten Reusch, Daniela Storch, Rudi Voss*

**P:559 Unique Insights from Historical Fisheries Survey Logbooks in the Arctic**
*John K. Pinnegar, Bryony L. Townhill, Georg H. Engelhard*

**P:556 Trophodynamics of Atlantic cod (Gadus morhua) on the Greenland continental shelf 2006-2010 and Spitsbergen 2010**
*Karl-Michael Werner, Sophia Kochalski, Jerome Chladek, Corinna Schendel, Heino O. Fock*

**P:433 Regional heterogeneity in climate change impacts on the living marine resources of the Arctic**
*Anne B. Hollowed, Wei Cheng, Harald Loeng, Libby Logerwell, Franz Mueter, James Reist*

**P:178 Cod response to past and current warm phases in the Seas of Iceland, a time series analysis**
*Marcos Llope, Niall McGinty, Joël Durant, Leif C. Stige, Guðrún Marteinsdóttir and Nils Chr. Stenseth*

**P:405 The Missing Middle: The Need for International Collaboration to Fill Gaps in Central Arctic Ocean Science**
*Henry P. Huntington, Thomas Van Pelt, Hyoung Chul Shin*

**P:644 Climate change impacts on the ecosystem services of Arctic cod (*Boreogadus saida*)**
*Benjamin J. Laurel, Louise A. Copeman*

# Summary of presentations

The Arctic environment is changing rapidly. In the Arctic, surface temperatures are rising twice the global average rate, and sea ice cover is declining dramatically. From the rapidly changing climate to the increase in human activities, there are many challenges affecting Arctic marine ecosystems. These challenges are being addressed in three Arctic regions in the ongoing Arctic Council project "Adaptation Actions for a Changing Arctic (AACA)."

The Arctic Monitoring and Assessment Programme (AMAP), a working group of the Arctic Council, and EU Horizon 2020 Coordination and Support Action EU-PolarNet co-sponsored this session. The session was well attended and consisted of 13 oral presentations and three poster presentations (see list below).

Presentations, P:450, P:502, and P:433, highlighted the role of heterogeneity of the Arctic with respect to hydrography, bathymetry, productivity regimes, and biodiversity. An important point that emerged from this session was that because of this heterogeneity; climate-warming effects will vary across the Arctic ecosystems. P:450 highlighted how variations in the response of hydrography differed between sub-regions within the Kara Sea, but, overall, ice condition was found to be the most important variable affecting hydrography. P:502 highlighted how differences in the resilience of Arctic benthos to perturbations, such as invasions, varied among five Arctic regions, with the two northernmost regions (i.e., the North Water Polynya and the Canadian Archipelago) being more resilient to invasions but less resilient to loss of ice-associated organisms such as sea-ice algae. The benthic communities of the Chukchi, Amundsen, and Beaufort Sea displayed less resilience. The authors of paper P:433 examined whether domain, temperature, and latitude matter with respect to climate change impacts on fish by studying six shelf domains. The Bering and Barents Seas were the most productive of the shelfs, whereas the Chukchi and Beaufort Seas were less productive. The models indicated the biggest changes are expected in the 2080-2100 time period. The authors concluded if we do nothing to mitigate the causes of climate change, we will see significant warming.

Presentations P:178, P:644, and P:129 presented evidence that species and whole community sensitivity to perturbations (e.g., temperature increase or invasive species) from climate warming will vary throughout the Arctic. For example, saffron cod and polar cod, although in the same family of fishes, have different temperature sensitivities and optima for growth and will respond differently to climate change. Whole communities may be more or less resilient or sensitive to perturbations, such as invasive species. Also, fish eggs may have different sensitivity to oil. P:178 showed food availability, temperature, and fishing are important drivers of Icelandic cod stocks. During warm-water regimes, food availability becomes an even more important driver, indicating that as the high-latitude ecosystems continue to warm, this effect may become even more pronounced. Even if fishing effort was removed from the model, there was still a significant effect of temperature. P:644 illustrated that gadoids have unique thermal responses, implying growth efficiencies are temperature-dependent and climate warming will not affect all gadoid species in Arctic waters equally. A laboratory experiment showed saffron cod performed well at higher temperatures. The most negative effect from climate warming will be on polar cod (*Boreogadus saida*), a key species in the marine Arctic, which provides a unique and valuable ecosystem service by efficiently channeling rich lipid energy to higher trophic levels at cold temperatures. P:129 described how continued warming and loss of sea ice is projected to shift the Chukchi Sea ecosystem from a benthic-dominated system to a more pelagic-dominated system. The authors conducted integrated ecosystem surveys during August to September in 2007, 2012, and 2013 in the U.S. Chukchi Sea. More juvenile pink salmon were captured in 2007, a warmer year, which likely increased pelagic productivity that led to larger (i.e., higher marine survival) and more abundance of juvenile pink salmon compared to the colder years of 2012 and 2013.

Scientists estimate the ocean is 30% more acidic today than it was 300 years ago. Because the waters of the Arctic are both old and cold, scientists expect the Arctic to experience the effects of ocean acidification faster and more seriously than lower latitudes. Data are currently lacking regarding effects of ocean acidification in the region. The authors of P:248 used biological and economic models to determine what may happen in the Baffin Bay/Davis Strait shrimp fishery as a result of ocean acidification. However, at this stage, it is hard to say whether shrimp in Greenland are affected by ocean acidification. P:268 described a study looking at the effect of food concentration on Atlantic cod survival and found no effect. The authors also described preliminary results regarding temperature effects on the western Baltic stock of Atlantic cod. The correlative analyses revealed strongest impact of temperature on recruitment in November and March. They found the stock collapsed even before a 2°C increase and, with increasing temperatures, profits are likely to decrease.

With diminishing sea ice, anthropogenic activities such as shipping and oil and gas exploration and development have increased in the Arctic. Presentations P:647, P:280, and P:445 described the risks associated with various anthropogenic activities and presented risk management and assessment tools. Using the Lofotens and Barents Sea, Norway, Howell et al. (P:647) developed a risk management tool to predict a range of possibilities regarding impacts of oil development on fish species in the region, running the model in hind cast. The model is still being developed and tested. They found that haddock eggs are more vulnerable to potential oil spills than cod eggs. Therefore, key species need to be investigated separately.

An increase in shipping leads to the increased possibility of oil spills and the spread of invasive species. To date, most risk assessments have only focused on single species and are qualitative. Nevalainen et al. (P:280) developed a model using a holistic food-web approach.

Species are not equally sensitive to oils spills, but data are limited. Therefore, models should focus on key functional groups instead of individual species. The models should be probabilistic to take uncertainty into account. Warming Arctic conditions and increased shipping favor the establishment of temperate invasive species in the region. Howland et al. (P:445) are using models to determine the likelihood of suitable habitat for invasive species in areas of the Canadian Arctic, with a focus on benthic species in port areas. They found sea surface temperature, ice concentration, and bathymetry to be the most important variables for species spread, and nearly all species exhibited future poleward gains. Currently, they are conducting screening level risk assessments to rank 30 species through a rapid assessment tool.

It became evident during the session that lack of data of the Arctic marine ecosystems is a major issue. In some cases, there truly are no data regarding a certain region or resource; however, in other cases, data have been collected but are not readily available. Both are problematic. Researchers have been reviewing logbooks of United Kingdom expeditions to the Arctic conducted between 1930 and 1977 (P:559) with data from the logbooks of 1930-1959 already digitized. They have uncovered data from cod catches and cod diet studies that will allow comparisons with today's data and conditions. The final paper (P:405) discussed the importance of filling the data gap in the central Arctic Ocean. There are data on the physical oceanography, lower trophic levels, and seabirds and marine mammals, but there are relatively little to no data available for fish in the Arctic Ocean. With the signing of a declaration by the five Arctic coastal states in July 2015 and the continuing negotiations between the five Arctic coastal states, China, the European Union, Iceland, Japan, and Korea to sign an agreement that they will not fish in the central Arctic Ocean until more fish data are available, it is crucial to fill the data gap. International collaboration on the science will be key to filling in the "missing middle."

Paper P:502 (Friscourt et al.) won Best Oral Presentation by an Early Career Scientist.

*Noatak National Preserve, Alaska. NPS Climate Change Response*

PART C

# AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Climate-related Effects on the Arctic Cryosphere and Adaptation Options

Reston, VA, USA, 28 April 2017

## Contents

# Executive Summary

Based on the presentations and discussions at the AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Climate-related Effects on the Arctic Cryosphere and Adaptation Options, a number of priority research issues were identified.

There is a critical need to estimate the ***economic cost of adaptation*** at both the Arctic scale and the global scale. Strong links to global connections are needed because changes in the Arctic are so large that they will feed back into changes in atmospheric circulation and global sea-level rise that will have major effects globally, implying very large and expensive requirements for adaptation on a global scale. An economic assessment of Arctic changes needs to be connected to the economic cost of the consequences.

In addition to the identification of research needs, ***coordination of research*** is needed. Coordination is important to manage limited time and money, and different competencies and strengths. An aspect of this is the need for a forum to address transdisciplinary research issues. Single-discipline silos need to be broken down and natural sciences and social sciences need to be brought together with stakeholder input to broaden the recommendations for research. Better means and instruments of attracting the input from a wider audience of stakeholders should be investigated and tested.

***Monitoring climate-related changes*** in the Arctic cryosphere at the system level and across disciplines is very important and requires a consistent commitment from funding agencies for long-term monitoring, which is vital given the rapid changes in these systems owing to changing stressors. Funding for the development and maintenance of interdisciplinary networks is also crucial.

***Making existing knowledge available in a form that can be used in the context of decision-making*** is at least as important as identifying research needs and filling scientific knowledge gaps. There is a need to investigate how natural sciences and knowledge intersect with social sciences and ***how natural science feeds into social science, policy development***, and other needs so that there is a better understanding of the need for funding and so that the scientific information provided will be appropriate to its intended use. There is a mismatch between organizational structures and funding structures. An institutional analysis should be conducted to determine whether the underlying social structure helps or hinders utilization of scientific information and the funding of adaptation options.

To ***increase the societal relevance and uptake of Arctic research***, knowledge should be obtained on how scientific research is applied in practice and how it feeds back into the trajectory of the multiple systems (e.g., geophysical, ecological) that are the focus of Arctic research. There is a need to engage with the relevant diverse communities (e.g., of knowledge holders, scientists, policy-makers, managers) at the outset when formulating research questions and designing research programs. Insights are provided by systems science, and by social and political science.

Recommendations for scientific research on the various components of the cryosphere often address narrow questions, resulting in a mismatch between consideration of narrow scientific issues and their relation to broader social systems. Extrapolating from the complexity of physical or ecological systems to global impacts also needs to be addressed.

In order to understand ecosystem services, and how we can manage for their continued provision including in an economic context, ***good understanding is needed of the geophysical, ecological, and social systems involved and how they are coupled***. Ecosystem services are numerous and relevant across scales; they are provided by nature and valued by people, so in essence they are co-produced in social-ecological systems. This is relevant at various scales as the drivers, including environmental, governance, and influencing actors are often different across these scales.

Information on and understanding of the physical sciences is very important to climate-related adaptation measures. There is a large ***need for knowledge regarding climate adaptation in the Arctic*** as well as on the global scale, given that the effects will be felt outside the Arctic region.

***Research is needed to develop action plans*** for small-scale industrial development and extra knowledge is needed of the economy and how to develop economic activities. There is need for a framework for helping communities to diversify their activities and take advantage of any opportunities presented by climate change. In considering local adaptation actions, experience from scientific assessments is available but there is also a need for the involvement of representatives from industry, shipping, mining and local residents. There is a need to test ways and means that local communities can use to adapt to climate change, including both short-term and long-term changes, so that this information can be used to teach university students about adaptation to climate change.

***Capacity building and policy-making are important at the local level*** as well as in broader regional areas. This should include the enhancement of education and training opportunities and job possibilities with good working conditions to develop these Arctic communities.

The need for ***early inclusion of Indigenous people and use of Indigenous knowledge in scientific studies*** and the development of climate-adaptation actions in the Arctic is vital. Indigenous people and communities need to be included more closely in scientific research. Indigenous knowledge gained over many centuries should be captured now while it still exists so that we can understand and utilize this thousand-year-old knowledge. There is need for developing priorities on using different kinds of knowledge and understanding; this requires a framework for implementation.

# C1 Background

The Arctic cryosphere is experiencing rapid change as a consequence of the rapidly changing climate. The sea-ice cover is decreasing rapidly, snow cover duration is decreasing, the melting of glaciers and the Greenland ice sheet is increasing, and permafrost is thawing in a number of areas. The Arctic Monitoring and Assessment Programme (AMAP) has studied these changes over the past 25 years and prepared assessment reports documenting the changes and their impacts. In 2017, the fourth assessment of physical changes in the Arctic cryosphere was completed, entitled *Snow, Water, Ice and Permafrost in the Arctic 2017 (SWIPA2017)* (AMAP, 2017a). In parallel, AMAP coordinated the Adaptation Actions for a Changing Arctic (AACA) process, which assessed the impacts of climate change and other stressors on the ecosystem services, human societies and socio-economic conditions of several regions in the Arctic (AMAP, 2017b,c, 2018), providing parallel, complementary information to SWIPA2017. The results of these four assessments and other recent AMAP work were presented at the AMAP-organized event 'International Conference on Arctic Science: Bringing Knowledge to Action'.

AMAP, as a partner in the Horizon 2020 coordination and support action EU-PolarNet, is responsible for promoting trans-Atlantic research activities between EU countries and the USA and Canada and, as one aspect of this, to hold international stakeholder workshops to determine common research needs that can be provided as input to the central EU-PolarNet requirement, namely, to develop an Integrated European Polar Research Programme together with an implementation plan. An important aspect of EU-PolarNet is 'connecting science with society', under which dialogue and cooperation with relevant Arctic stakeholders will ensure their input to the formulation of this research program. The AMAP / EU-PolarNet Stakeholder Workshop on Research Needs on Climate-related Effects on the Arctic Cryosphere and Adaptation Options is the third of four AMAP-organized stakeholder workshops to identify and formulate key Arctic research needs over the five years of the project. The central theme of this workshop was the identification of research needed to obtain a better understanding of the dynamic processes, linkages and feedbacks of the climate-related changes in the Arctic cryosphere and potential options for adaptation to such changes by residents, communities and regions in the Arctic.

The stakeholder workshop was held immediately following the AMAP International Conference on Arctic Science: Bringing Knowledge to Action, so that it could use the presentations and discussions at the conference as a basis for consideration of knowledge gaps and research needs at the workshop.

The format of the workshop, after the introductory presentations setting the background and aims, comprised presentations by several experts from around the Circumpolar North on a specific theme followed by discussion by the participants of the ideas presented and identification of research needs requiring further work. The workshop participants, as a group, then considered all material presented to identify key themes and approaches.

# C2 Opening and welcome

The Co-Chairs of the Workshop, Morten Skovgaard Olsen (Danish Ministry of Energy, Utilities and Climate) and Jim Overland (NOAA Pacific Marine Environmental Laboratory) opened the meeting and welcomed the participants.

Representatives of the two co-sponsors of the workshop, AMAP and EU-PolarNet, then provided the overall background for the workshop.

Lars-Otto Reiersen, AMAP Executive Secretary, welcomed the participants to the workshop. He noted the significance of this workshop to identify research needs relating to climate impacts on the Arctic cryosphere and adaption options for Arctic communities that can be provided to the European Commission in relation to their funding activities. The results should also be useful to AMAP and other organizations coordinating or conducting international or national investigations in the Arctic.

# C3 Context of the workshop: Research needs defined for EU-PolarNet work

Nicole Biebow, Project Manager of EU-PolarNet, presented a brief overview of this activity. She stated the European Union and its executive body, the European Commission (EC), attribute an increasing importance to science and innovation in the high latitudes. As a result, the EC launched a five-year coordination and support action 'EU-PolarNet – Connecting Science with Society', which is working in close cooperation with the EC to shape Europe's polar research and policy agenda. EU-PolarNet is the largest consortium of expertise and infrastructure for polar research, comprising 17 countries represented by 22 of Europe's internationally respected multidisciplinary research institutes. EU-PolarNet is working closely together with the EC, providing support and advice on all issues related to the polar regions.

An important aim of EU-PolarNet is to develop an Integrated European Research Programme for the Antarctic and the Arctic; this will be co-designed with all relevant stakeholders and coordinated with the activities of many other polar research nations beyond Europe, including Canada and the United States, with which consortium partners already have productive links. The AMAP / EU-PolarNet Workshop on Research Needs on Climate-related Effects on the Arctic Cryosphere and Adaptation Options is one important step in obtaining input from researchers and stakeholders for the Integrated European Polar Research Programme.

EU-PolarNet is also designing a resource-oriented European infrastructure access and usage plan for polar research. It is working to improve and strengthen international cooperation and implement the Trans-Atlantic Ocean Research Alliance between the EU, Canada and the USA. EU-PolarNet will continue to assist the EC in defining calls for the 2018–2020 H2020 program, which will allocate a significant amount of funding to Arctic and Antarctic research.

An early activity of the project was to determine the polar research priorities in European countries. Based on an extensive compilation of national and institutional priority issues, ten research themes were chosen that reflected research strategies in most of the plans. These were then related to societal goals.

The next step is to develop six White Papers to promote urgent polar research questions. This will build on a public online consultation to enable scientific and non-scientific stakeholders to indicate what they consider are the most important topics in the polar regions that should be tackled by future research questions and key issues of societal relevance. The White Papers will be developed jointly by stakeholders and scientific experts during a five-day meeting near Madrid. Further information can be found on http://www.eu-polarnet.eu/.

# C4 Aims and outcome of the workshop

The workshop organizer and meeting rapporteur, Janet Pawlak, AMAP Deputy Executive Secretary, emphasized the importance of this workshop as one of the stakeholder contributions to the further development of prioritized objectives for Arctic research and ultimately the Integrated European Research Programme for the Arctic. As climate-related effects on the Arctic cryosphere and adaptation options represent only one of many research topics for the Arctic, this workshop should aim to identify the most important research needs on this topic. These research needs will be included in the report to be prepared based on the presentations and discussions at the workshop for submission to EU-PolarNet as a stakeholder contribution on these issues. The report is also a project deliverable to the European Commission for its information and use.

# C5 Research needs on climate-related effects on the Arctic cryosphere

## C5.1 Summary of research needs from the AMAP conference

Ross Brown, Environment Canada, gave an overview of the research needs on climate-related effects on the Arctic cryosphere that he heard articulated at the AMAP conference. These include:

1. There is a need for improved understanding of dynamic processes, linkages and feedbacks in the climate system. Currently, models are developed in 'silos' without looking at interfaces between systems. Important knowledge gaps are that critical processes are not covered and small-scale processes are not represented in the models. There is also a need to reduce the current large spread in model outcomes. Model Intercomparison Projects (MIPs) tend to be silos, covering each separate component of the cryosphere; there is a need for a more integrated approach and data sets need to be made available for that process. Users have not been taken into account in the conduct of MIPs.
2. There is a need to narrow uncertainties in observed trends and variability in the amount of seasonal snow cover and for the development of realistic gridded values of historic precipitation. Multiple data sets are needed to establish uncertainties in Arctic precipitation; surface snow depth and precipitation observing points are needed.
3. An improved understanding of the impacts of the transition of the Arctic to a rain-dominated precipitation regime is needed; this requires a multidisciplinary research framework.
4. An improved understanding of the risk of abrupt cooling events in the Northwest Atlantic from a shutdown of the subpolar gyre is needed. There is an estimated 45% chance of a shutdown in the 21st century. There is a need to improve the quantification of the freshwater system.
5. Northern community needs for environmental information for decision making are not being met; special attention is needed to improve this information, also in close collaboration with each particular community.

There are initiatives underway for weather and climate model improvement as well as successful models for moving knowledge to action that can be implemented on a broader basis.

A comment to this presentation indicated the importance of linking biodiversity and ecosystem functions to community needs.

## C5.2 Research needs on climate-related effects on the Arctic cryosphere: marine systems

David Barber, University of Manitoba, Winnipeg, Canada, noted that motivating principles for research into the effects of changes in the Arctic cryosphere on marine systems include that the Arctic Ocean and its regional seas are now open for development. Furthermore, there is increasing evidence that the Arctic plays a role in lower latitude climate and weather processes. Teleconnections and high-frequency processes (e.g., storms) are poorly understood, and thus poorly modeled. Sea ice is a critical habitat for marine organisms to succeed. Changes in the Arctic are causing changes in predator-prey interactions, and we do not know what influence climate change will have on marine productivity, biomass or biodiversity. Ocean acidification is occurring but is still poorly understood and we do not know whether the Arctic Ocean will become an overall source or sink for carbon dioxide.

Sustainable solutions to these issues will require true northern engagement with science and policy and there is a growing recognition that international coordination is required to address these major issues at pertinent scales, both in time and space.

David Barber highlighted the need for research on the following topics:

- The double gyre pattern for movement of sea ice in the Arctic Ocean, which is based on atmospheric circulation, needs study; if there is a change in the gyre pattern, there will be a change in the atmospheric circulation.
- The various ice forms have not been studied adequately and this affects their interpretation in satellite images; for example, rotten ice shows up as multi-year ice in satellite images. Ice also changes from dark to light periods and this needs studying.
- There is a need to better understand freshwater coupling with the marine system; there is much more freshwater in the Arctic now and this affects physical and biogeochemical parts of the system. The coupling between fresh and marine waters is complex, and freshwater flows under the ice, changing conditions for marine organisms.

- There is a need to work with industry to develop better observing and measurement resources. In Canada, marine transportation corridors are developing through the Arctic but baselines and bathymetry maps do not exist for some of these areas. Environmental data from the coastguard, defense, regulatory agencies, Indigenous organizations and industry need to be merged to create a broader picture of these new corridors.
- Baselines for sea-ice habitats need to be established; the biological aspects of marine science in the Arctic are poorly known and there is no knowledge about bacteria in sea ice.
- It is important to apply emerging technologies to the development of autonomous systems for observations in the Arctic and sustained observing systems need to be established for long-term observations. This should include technology development and integrated data systems. Indigenous community monitoring programs are also important in this regard.

Economic development is now also driving much research in certain regions, such as in northern Canada.

In the discussion, it was considered that more research is needed on carbon processes and the connection between the marine and terrestrial environments as well as freshwater processes and their connection with sea ice. Another poorly understood topic is the coupling between the atmosphere and sea ice; their interactive processes are not understood well. Different views have also been expressed concerning the potential risk of the shutdown of the North Atlantic circulation; however, it was noted that there is a large amount of freshwater stored in the gyres in the Arctic Ocean. The Beaufort Gyre has been storing water for over ten years and a release could occur. Observations also indicate that the Atlantic meridional overturning circulation is slowing down.

### C5.3 Research needs on climate-related effects on the Arctic cryosphere: terrestrial systems

Vladimir Romanovsky, University of Alaska Fairbanks, noted that three key priorities from the International Arctic Science Committee (IASC) third International Conference on Arctic Research Planning (ICARP III) serve as a useful framework for the consideration of research needs. These key science priorities are: 1) the role of the Arctic in the global system; 2) observing and predicting future climate dynamics and ecosystem responses; and 3) understanding the vulnerability and resilience of Arctic environments and societies and supporting sustainable development.

Regarding the role of changes in the terrestrial cryosphere in a changing global system, these include a) changes in the snow amount, timing and distribution, which influence changes in global albedo, hydrology, vegetation, etc.; b) changes in the amount and distribution of land-based ice masses, which influence changes in global sea level, albedo, hydrology, etc.; and c) changes in permafrost and coastal erosion, which result in changes in the carbon cycle, hydrology, vegetation, etc. Although these changes may not seem so significant to scientists who are not involved in Arctic studies, in reality changes in snow amount, timing and distribution under a warmer climate affect the complex interplay and interrelation with changing air temperature, precipitation, wind, topography and micro-topography, vegetation, etc. Changes in the other terrestrial components of the cryosphere similarly affect the complex interplay with the various relevant systems. The major priority is to emphasize interactions among these systems. While many of these interactions and internal feedbacks are known, they are not adequately understood and often not included in the global or even the regional Earth System Models (ESMs). For this reason, recent ESMs do not produce good results in modeling snow, terrestrial ice masses, and permafrost. As an example, there is such a wide range of model results for permafrost extent that they are useless. Changes to the terrestrial cryosphere give feedbacks to the global climate, but there is a need to model them correctly to determine how important these feedbacks are.

With regard to observing and predicting future climate dynamics and ecosystem responses and understanding the vulnerability and resilience of Arctic environments and societies, there is an urgent necessity to make measurable progress in studying, understanding, and successfully modeling the internal interrelations and feedbacks in the terrestrial cryospheric components of the Arctic system. This needs to be done at relevant smaller scales, which requires very high resolution measurements and modeling. Furthermore, the variability of all components is so large that there may be different conditions only 50 meters away. This requires a large amount of data and raises the question of how this variability should be expressed in our research and how knowledge of variability can be made useful.

It is also necessary to be able to provide scientifically sound projections of changes in these components into the future to enable the relevant stakeholders to plan all necessary measures that will ensure sustainable development of Arctic communities. The challenge in making progress in this direction is also associated with the high degree of spatial variability in the related natural processes and environmental characteristics of terrestrial cryospheric components.

Among the challenges is the need for permafrost science to become truly multidisciplinary and interdisciplinary. There is also a need to develop new, advanced observational methods that include both ground-based methods and remote sensing, as well as a combination of the two, to optimize the observational network and to upscale the point observations. A 30-m resolution is possible from Landsat images with some ground measurements for a list of ecotypes; this knowledge can be used to organize a measurement system and determine where to place measurement stations with the aid of an ecotype map. This strategy has been used in Alaska by which measurement stations in a specific area of the state were chosen according to ecotype, and various simple and inexpensive measurements were taken to determine how the different ecotypes respond to temperature changes. The area studied contains about twenty common ecotypes as well as a few uncommon ecotypes. The measurements covered approximately 90% of all ecotypes in that area. They showed that permafrost characteristics are similar for similar ecotypes; for example, tussock tundra permafrost is the same for upland and lowland areas. Moss cover is very important for the presence of permafrost. Thus, an ecotype map can be converted to a permafrost map. These measurements could also be used to upscale the point information; this has worked well for permafrost and it may also be possible for snow and other components. A description of the system used in Alaska can be found at www.permafrostwatch.org.

### C5.4 Discussion: Research needs on climate-related effects on the Arctic cryosphere

It was noted that for all cryospheric components, there is a question of how the Arctic affects the global system. There is a gap between looking at complexities on a regional level and in the broader climate models. This raised the question of how EU-PolarNet can start to bridge the gap between regional complexities and global issues.

It was pointed out that the U.S. Department of Energy is developing a model to handle this complexity for the terrestrial areas in Alaska. It is not a grid model, but a coarser-scale model of watersheds. It is possible to do more if not limited by classical grids. The next phase of this work will broaden it from only Alaska to the circumpolar North and will work with other modeling and measurement communities in one to five years. This project covers many components and makes use of a number of other projects.

Regarding upscaling complexity for the Arctic marine areas, high-resolution general circulation models and regional models are being used, but some processes are not understood well enough to model and the system is changing very quickly making it even more difficult.

Furthermore, it was noted that it is very difficult to understand complex systems. We can look at some components and determine how they relate to other components; for example, in relating temperature to elevation and to radiation feedbacks, one can approach feedback by going from coarse resolution to high resolution. However, it was pointed out that the marine system is much too dynamic to obtain a high resolution and it is also changing very rapidly.

The question was raised as to whether there is a need to scale to the pan-Arctic level. There are audiences for different scales as well as many important questions at much smaller scales.

The NOAA model gives incorrect results for snow cover, but it is still being used in publications. A collaborative project should compare the different models and determine the most accurate for each cryosphere component. There is a need for commonly defined protocol to improve performance. As an example, the SnowPEX project was an intercomparison and validation of hemispheric and global satellite snow products.

## C6 Research needs on adaptation options for climate-related effects on the Arctic cryosphere

### C6.1 Summary of research needs from the AMAP conference

Larry Hinzman, University of Alaska Fairbanks, stated that he had requested a number of participants at the conference to provide input on this topic from the presentations and discussions at the sessions they had attended. He had received a great deal of input and expressed his appreciation to all who had contributed.

Larry Hinzman noted that Arctic human development (or Arctic social well-being) is defined across the domains of health and population, material wellbeing, education, cultural vitality, contact with nature, and self-determination, but we are lacking the systems and support for maintaining on a regular basis the data necessary to feed indicators within these identified domains. The obstacles primarily relate to data access, costs, and privacy issues.

There is a need to address methodological and knowledge gaps in evaluating adaptation actions over time and to obtain a better understanding of how adaptation actions may set up path dependencies by either facilitating or constraining future action. There is also a need to better understand the cumulative impacts of climate change, industrial development and societal change. Explanatory social science approaches to adaptation are needed that should include behavioral sciences and institutional and policy analysis. There is a knowledge gap in relation to interdisciplinary work that could better engage the social sciences in adaptation research, especially in relation to psychology, communication and decision sciences. However, making existing knowledge available in a form that can be used in the context of decision-making is at least as important as identifying research needs and filling scientific knowledge gaps.

There is a need for more research across scales and on engaging the changing economic opportunities associated with shipping and resource development, in addition to impacts on Indigenous practices. Furthermore, longitudinal studies are required to assess the effectiveness of adaptation actions and for international comparisons with other regions.

The scientific community working on climate change and adaptation issues should help to improve the education systems for northern populations so that they can better take charge of their adaptation strategies. The impacts of changes in the cryosphere on ecosystems and their living resources, particularly the traditional and country food sources, need further study. The role and effects of contaminants in local foods and the impacts of climate change on health also need greater investigation. There is a need to understand the role that climate warming plays in the release of contaminants and disease vectors in the environment, as well as the risk associated with the transmission of disease vectors from the environment to animals and ultimately to humans, and where climate warming will exacerbate these problems. Further research is needed on how risk communication on contaminants is practiced in Arctic countries and on appropriate methodologies for developing and deploying risk communication messages and evaluating the effectiveness of the communication strategies.

Specific to the Bering/Chukchi/Beaufort region is an identified need for innovation in the process of conducting scientific research that genuinely engages and partners with Indigenous communities in a way that substantively builds adaptive capacity to multiple stressors and achieves locally defined goals.

Multiple stressors are interacting in the Arctic today: rapid change (environment, climate, socio-economic conditions), the latter driven by industrial developments (extractive industries), tourism, migration, urbanization, new technologies, economic challenges and opportunities. Climate change may not be the main challenge, but it exacerbates existing challenges. Adaptation to these challenges is context-dependent and a social process, but it also involves all levels of management and decision-making.

The suite of Arctic indicators is seriously deficient in biological and economic indicators at scales from community to regional level. There is a need for indicators that integrate the effects of multiple stressors, i.e., integrative indices of stress on communities in Arctic regions. Integration can be across physical (climate), social and economic domains. There is a need for better metrics or indicators of cumulative impacts of change, with cumulative meaning over time and/or over climate change, industrial development and societal change.

In the discussion of this presentation, it was considered that the overarching issue with relation to adaptation is to determine what is needed to maintain everyday life and develop a good quality of life in the Arctic. Cultural adaptation and social adaptation are strongly linked and the preservation of culture is strongly linked with the preservation of life. A loss of culture leads to a loss of life. There is a need to develop models for sustainable communities in the Arctic.

## C6.2 Research needs on adaptation options for climate-related effects on the Arctic cryosphere: risks to food security and human health

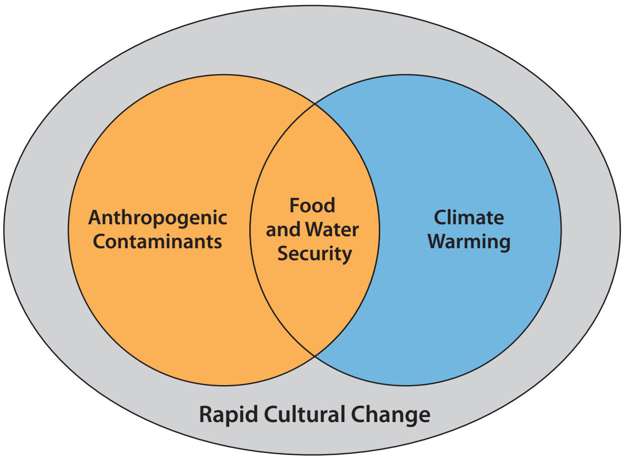


Figure C1 A confluence of changes affect rural Arctic communities.

James E. Berner, Alaska Native Tribal Health Consortium (ANTHC), Anchorage, Alaska, stated that climate-mediated environmental threats to human health comprise major threats to circumpolar communities (Figure C1). Increased transport of environmental contaminants to the Arctic, resulting in increased tissue levels of contaminants in Arctic wildlife, may increase their susceptibility to active infection with endemic or new pathogens. This, in turn, would likely result in mortality of these species and possibly increased risk of exposure of human consumers to zoonotic (animal-borne) diseases as well as increased levels of contaminants. Increased tissue levels of contaminants in subsistence species will decrease their immune response to endemic zoonotic diseases, such as Brucella and Toxoplasma. This immunosuppression may also affect humans.

The Arctic influences ocean circulation and north-flowing currents carry contaminants from more densely populated regions south of the Arctic, where marine organisms are also exposed to higher concentrations of contaminants. Concentrations of contaminants in Pacific salmon returning to Alaska are mirrored in their human consumers.

Local sources of contaminants also occur in the Arctic. This is particularly the case in Russia, where old drums that have contained PCBs are rusting and leaking contaminants into the soil and waterways. This results in very large concentrations of PCBs in walrus meat that has been treated by traditional methods of fermentation in a ground pit in Chukotka. Continued use of DDT also has an influence on soil sources of contamination.

Consumption of marine mammals from the Bering Sea is a source of contaminant exposure for Arctic residents, with concentrations of contaminants particularly high in ribbon seals. To determine levels of exposure to contaminants, two Alaska native biomonitoring programs (the Alaska Native Maternal Organics Monitoring (MOM) and the Rural Alaska Monitoring Program (RAMP) Study) and one village-based observer (the Local Environmental Observer (LEO)) program have been established to gather data in rural Alaska. All three are supported by the U.S. Environmental Protection Agency.

The MOM study is part of a circumpolar network of maternal monitoring programs and is sponsored by the Arctic Council. The objectives are to systematically collect and interpret information on contaminants, follow trends in exposure and provide data for risk reduction strategies. The detection of emerging threats is also important, as well as creation of a specimen bank for retrospective analyses.

The RAMP biomonitoring initiative enables communities to monitor contaminants in their own specimens. The residents operate the monitoring program and metrics are based on the assessment of environmental change by the individual village. RAMP focuses on food and water security in rural Alaska and uses a 'One Health' framework, which assumes that all parts of the ecosystem and environment are related and are affected by changes in any other part. This program started with monitoring antibodies in terrestrial and marine mammal blood collected by soaking filter paper in blood of hunter-killed animals to show exposure to zoonotic diseases, i.e., diseases that can infect both animals and humans. Blood levels of mercury, selenium and stable isotopes of carbon and nitrogen are now also being measured in these samples and organic contaminants will be tested in the future. There is a growing problem of harmful algal blooms (HABs) in the Arctic, so the program tests the stomach and intestinal contents of marine mammals for the HAB toxins saxitoxin (paralytic shellfish poisoning, PSP) and domoic acid (amnesic shellfish poisoning, ASP). Tests for these toxins are also performed in local freshwater sources, as thawing permafrost can release nitrogen and phosphorus into the water and stimulate HABs. With climate warming, beavers, muskrats and rabbits have moved farther north with the shift in the tree line, carrying ticks and mosquitos that may host the bacteria that cause the tularemia infection. RAMP tests for these bacteria.

Five zoonotic diseases are increasingly prevalent in Arctic wildlife: toxoplasmosis (in about 50% of harbor seals); trichinosis (very common in polar bears and walrus); brucellosis (10–25% of caribou); tularemia (beaver, muskrat, snowshoe hare); and Q-fever (*Coxiella burnetti*) (75% of fur seals).

Shellfish, particularly clams and mussels, are a subsistence resource harvested from the beaches in Northwest Alaska; they have historically been free of PSP but they are vulnerable to changing ocean conditions. However, now algal toxins are prevalent on all coasts of Alaska and both saxitoxin and domoic acid have been detected in a wide range of species of marine mammals harvested or stranded on the coast.

The RAMP and LEO programs are being expanded in North America and beyond and will be useful for observing the spread of disease and contaminants and how that relates to climate change. Community biomonitoring allows for many more specimens to be analyzed, improved local risk-appraisal, correlation with climate and oceanographic data, collection of regional data on pathogen movement trends in a species disease exposure, detection of emerging infectious and contaminant threats, and the creation of specimen biobanks. The most immediate application of RAMP data is the creation of a community-specific adaptation plan, allowing residents to reduce exposure to the subset of vulnerable residents, including pregnant mothers, infants, the elderly, residents suffering from immunosuppression owing to chemotherapy or other reasons, and those with chronic diseases.

Research needs include:

- Continued monitoring of maternal contaminant exposure and long-term monitoring to detect health effects; this will be needed for the foreseeable future as contaminants continue to be distributed by riverine, oceanic and atmospheric transport.
- Continued testing of appropriate marine mammal matrices for HAB toxins. Saxitoxin forms in ice seals in the different parts of the Arctic should be investigated using high-performance liquid chromatography to determine whether the toxin is being formed by the same plankton species in all regions of the Arctic.
- Investigations of effects of HABs on marine mammal genes.

## C6.3 Research needs on adaptation options for climate-related effects on the Arctic cryosphere: natural hazards

Katia Kontar, University of Alaska Fairbanks, stated that the Arctic is prone to many natural hazards that could result in natural disasters. Natural hazards are physical phenomena caused by rapid or slow onset events that could potentially cause a severe threat to humans and their welfare; autumn storms are a rapid onset hazard that increases erosion of the coast. Climate change is a slow onset hazard affecting many other hazards. A disaster is a disruptive and destructive event that results from a hazard, and overwhelms the affected communities and their ability to cope with the consequences. Since the 1980s, the number and severity of disasters has been increasing, with the number of disasters more than doubling (Figure C2).

Climate change and natural hazards need to be considered together because currently they are the subject of two different multidisciplinary communities of research and practice. Climate change increases the magnitude and frequency of some natural hazards, including floods, erosion, permafrost thaw and slope instability. In Alaska, 86% of Alaska Native villages are affected by flooding and erosion, part of which is caused by rising temperatures.

The goal is to minimize the negative impacts of climate change and natural hazards. This can be done through mitigation, including structural measures on buildings and non-structural measures such as building codes; preparedness, including monitoring and warnings; and as a last resort relocation, which is very difficult and not satisfactory. An example of this is the need to relocate the village of Kivalina in Alaska, which is heavily affected by coastal erosion. Climate change and natural hazards are complex natural and social phenomena: human activities, such as emissions of greenhouse gases and building houses in vulnerable areas, are key causes behind the negative impacts of natural events and humans continue to suffer from these negative impacts.

There is a need for more interdisciplinary research to identify the most appropriate options to address each hazard; every hazard and every at-risk community should be addressed individually. There is a need to identify the natural and socio-economic drivers of each hazard to be able to identify solutions. Increased engagement of all stakeholders is also needed to identify the best solutions. The negative impacts of climate change and natural hazards can be lessened through holistic policy solutions. These policies should be based on assessments of both physical sciences and social sciences and applying interdisciplinary research and stakeholder collaboration.

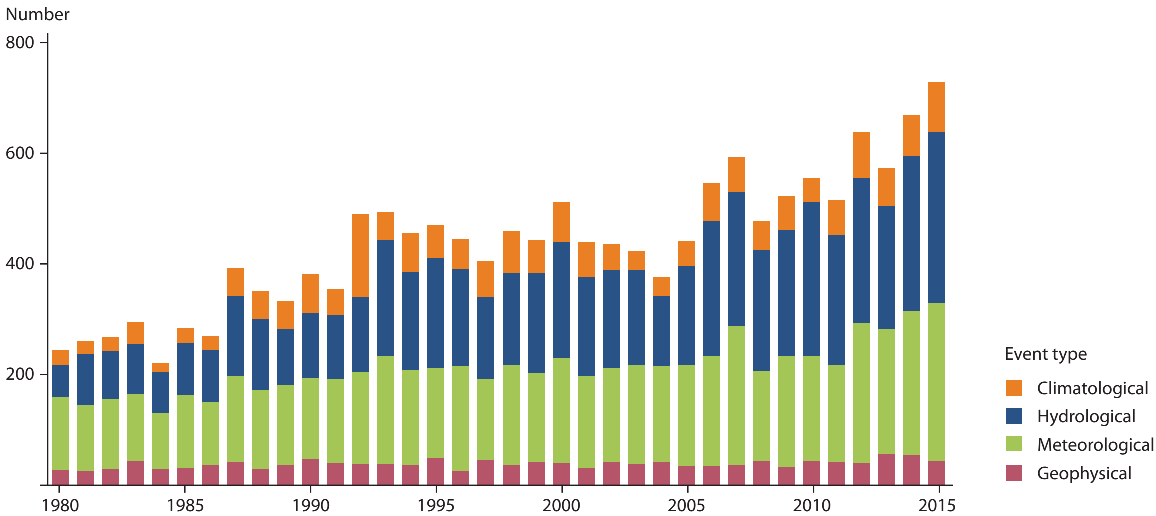


Figure C2 Loss events worldwide, 1980–2015. Number of relevant events by peril. Source: Münich Re (2016).

### C6.4 Discussion: Research needs for adaptation options for climate-related effects on the Arctic cryosphere

In the discussion of this presentation, the difference between mitigation and preparedness was noted: community preparedness involves becoming aware and informed about the potential hazards, while mitigation involves long-term preparation for hazards. Estimates have shown that the cost of investments in mitigation and proactive measures amount to approximately 10% of the cost of a disaster if it occurs. For example, the cost of coastal erosion in Alaska is very high.

## C7 Panel discussion – Research needs for Arctic climate-related effects

In the overall discussion of issues raised at the workshop, a number of points were made regarding research and other needs in relation to studies of climate-related changes in the Arctic cryosphere:

- In AMAP, there is an emphasis on the importance of monitoring at the system level and across disciplines; however, there is a problem for agencies to make a commitment to fund long-term monitoring. There is a need to maintain the funding for long-term monitoring because scientists are trying to describe systems while these systems are changing owing to the changing stressors.
- It is important to develop and maintain networks. The International Polar Year created networks across disciplines, but these networks have not been maintained because they need funding.
- There are some global institutions that conduct monitoring, such as the WMO Global Climate Monitoring System; however, there is still a need for national monitoring of physical parameters. The aim should be that modeling and observations at the national level will fit into the international system.
- There is a mismatch between organizational structures and funding structures. An institutional analysis should be conducted to determine whether the underlying social structure helps or hinders utilizing scientific information and funding adaptation options.

Issues mentioned in relation to the application of scientific information by society and communities for the development of adaptation options include:

- The SWIPA2017 chapters each contain recommendations for scientific research on the various components of the cryosphere; however, these recommendations address narrow questions from the report. There is a mismatch between addressing narrow scientific questions and bringing them together in relation to social systems. It is also difficult to extrapolate from the complexity of the system to global impacts. Furthermore, the best means of bringing science into society is often not clear.
- Information on and understanding of the physical sciences is very important to climate-related adaptation measures. For example, for the village of Kivalina, Alaska to receive funding for relocation, they need to know that the place where they want to move will still be stable in 20 to 30 years.
- Natural sciences are distinctly different from social sciences; it would be useful to investigate how natural sciences and knowledge intersect with social sciences.
- There is science available that focuses on how the knowledge that our scientific research produces is actually applied and feeds back into the trajectory of the multiple systems (e.g., geophysical, ecological) that much research in the Arctic is focused on. Insights are provided by systems science, and by social and political science; and if we want to increase the societal relevance and uptake of Arctic research, we should consider this body of knowledge and engage with the relevant diverse communities (e.g., of knowledge holders, scientists, policy-makers, managers) at the outset when we formulate research questions and design research programs.
- Science is needed on how knowledge passes through social systems and feeds back to ecological science; how does science feedback to social science, policy, and other needs so that it gives a better understanding for funding? As an example, if a policy issue is to increase resilience, social science can ask how this should be done.
- In order to understand ecosystem services, and understand how we can manage for their continued provision including in an economic context, we need good understanding of the geophysical, ecological, and social systems involved and how they are coupled. Ecosystem services are provided for by nature, but valued by people, so in essence they are co-produced in social-ecological systems. This is not only relevant at the local scale but also at the sub-regional scale (e.g., national; AACA regions; large marine ecosystems, LMEs) as the drivers, including environmental, governance arrangements, and influencing actors, are often different across these scales.
- In considering local adaptation actions, experience from scientific assessments is available but there is also a need for the involvement of representatives from industry, shipping, mining and local residents.
- There is a need to test ways and means that local communities can use to adapt to climate change, including both short-term and long-term changes, so that this information can be used to teach university students about adaptation to climate change. These results currently do not exist, so universities have no teaching materials on climate change adaptation solutions.

The issue of scale is important for both scientific understanding and adaptation actions:

- An issue regarding societal questions is the ability of societally posed questions to look at the scale of actions. When the issue of scale has been determined, decisions can be made on the level of the model to be used and on how information from other activities can be used. This process aids a thoughtful use of resources.
- There is a large need for knowledge regarding climate adaptation in the Arctic as well as on the global scale, given that the effects will be felt outside the Arctic region.

Nonetheless, climate change may present opportunities within the Arctic region for communities struggling with economic capacity and limitations in the region.

- For the AACA assessment of the Baffin Bay/Davis Strait region, much work was conducted to describe and make models and projections, but the long-term downscale projections were not adequate. It was not possible to inform communities relying on hunting and fishing on what will happen several decades from now. There is a need to encourage small-scale industries in these communities. Research is needed to develop action plans for small-scale industrial development and extra knowledge is needed of the economy and how to develop economic activities. There is need for a framework for helping communities to diversify their activities.
- Capacity building and policy-making are important at the local level as well as in broader regional areas. This should include the enhancement of education and training opportunities and job possibilities with good working conditions to develop these Arctic communities.
- The need for understanding ecosystem services is not only relevant in a local community context (e.g., small-scale subsistence hunting), but also in a much broader context, as ecosystem services are numerous and relevant across scales, including addressing their monitoring, governance and management needs.

The need for early inclusion of Indigenous people and use of Indigenous knowledge in scientific studies and the development of climate-adaptation actions in the Arctic received considerable discussion:

- In the Inuit community, people are considered part of the ecosystem and the cumulative impacts that are occurring. Communities have a sharing society and are all part of global interconnected systems. These communities have a great capacity and should receive greater empowerment; they have a great deal of experience with adaptation. They also have a need to receive scientific information on physical conditions and changes but owing to the way the scientific research is currently conducted, they are not receiving this information quickly enough. Indigenous people and communities need to be included more closely in scientific research. In the past, the typical way that small communities were included in multi-million dollar research projects was that the community received a 300-page research proposal several days before the deadline for its submission, meaning that there was no chance for the community to read and comment on it. There is a need to scale down from large scientific proposals to the people living in a small village who have long-term Indigenous knowledge of that area.
- However, scientists engaged in Arctic research are becoming better connected to local communities and there are more examples of new approaches to scientific research that bring in local knowledge and association with local communities.
- Indigenous knowledge is important; the first observation of regime change in the Bering Sea came from Indigenous studies of the contents of seal stomachs. Nonetheless, despite the importance of Indigenous knowledge, it cannot easily tackle new climate-related threats such as the changes affecting infrastructure in communities.
- Indigenous knowledge gained over many centuries should be captured now while it still exists so that we can understand and utilize this thousand-year-old knowledge.
- One problem is to bring together many different people to address the questions. Indigenous people are an important part of this. There is an urgency to include the people in the Arctic directly affected by the climate-related changes. The AMAP conference involved mainly scientists talking to scientists with very few Indigenous representatives or other stakeholders.
- Indigenous knowledge is very valuable, but owing to the major changes in the Arctic that will occur in future decades, a system should be developed so that Indigenous knowledge can be supplemented. However, most people do not understand Indigenous knowledge and how scientists and Indigenous knowledge-holders can work together. There is a scientific decision chain that involves many different types of people; there is need for developing priorities on using different kinds of knowledge and understanding. This requires a framework for implementation.

General points discussed included:

- Humans are part of the ecosystem and cumulative effects are both economic and environmental. Estimating the economic cost of adaptation at both the Arctic scale and the global scale is very important.
- There need to be strong links to global connections, and global stakeholders should be considered; for example, quantitative data exist on global sea-level rise. Sea level is important and sea-level rise is already locked into the system, particularly after 2050. While temperatures in mid-latitudes may stabilize at about 2°C, in Alaska a temperature increase of 4° to 5°C is projected. These changes are off scale and will feed back into changes in atmospheric circulation that will have major effects globally. They imply very large needs for adaptation on a global scale, which will be very expensive. There is a need to connect the economic assessment of Arctic changes to the economic cost of the consequences.
- We should decide what the most critical areas are that we should focus on.
- In addition to the identification of research needs, there are needs for coordination of research. There are different types of research, and on the coordination side there are different levels and skills of coordination. We need to evaluate what we are doing well and what we are not doing well.
- Different countries face different situations. When one country develops solutions to climate adaptation, efforts should be made to try to utilize them in other countries. An example is the cooperation between Russia and Alaska on natural hazards.
- Although this is a workshop intended to obtain ideas for research needs from a wide variety of relevant Arctic stakeholders, most participants were from the scientific community. This is indicative of the problem of attracting other types of stakeholders to such workshops. For example,

industry representatives have not attended these workshops, perhaps because they are not interested in the subject or do not have the time. There are so many different priorities and they are difficult to address. This raises the question of what type of instruments could be used to attract a wider audience of stakeholders.

- How to foster broader engagement is both a practical and a social research question; there is need for both analysis and practice and the need for a bridge between the community level and higher scales comes into play.
- Coordination is important, both to manage limited time and money as well as to manage different competencies and strengths. There is need for a forum in which transdisciplinary issues can be addressed for research needs.

## C8 Final remarks and closing of meeting

On behalf of EU-PolarNet, Nicole Biebow thanked the workshop participants for their insights on the many topics discussed. She noted that we currently often work in single-discipline silos; we need to ensure that we have representation of people who can contribute to all of these topics. In its White Paper process the EU-PolarNet will move beyond this because the EU wants to include economic, societal, and technological issues all in one topic. Silos need to be broken down and technology needs to be considered also. Nicole Biebow stated that the report that will be prepared based on this workshop will feed directly into the research development process and the White Paper conference, which will develop recommendations on a much broader scale than that discussed at this workshop. The aim is to integrate physical and social sciences and to bring natural science and social science together with stakeholders to broaden the recommendations for research. The Co-Chairs thanked the speakers and all the participants for their valuable insights and suggestions, and then closed the meeting.

### References

AMAP, 2017a. Snow, Water, Ice and Permafrost in the Arctic (SWIPA) 2017. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xiv + 269 pp.

AMAP, 2017b. Adaptation Actions for a Changing Arctic: Perspectives from the Bering-Chukchi-Beaufort Region. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xiv + 255 pp

AMAP, 2017c. Adaptation Actions for a Changing Arctic: Perspectives from the Barents Area. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xiv + 267pp

AMAP, 2018. Adaptation Actions for a Changing Arctic: Perspectives from the Baffin Bay/Davis Strait Region. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xvi + 354pp

Münich Re, 2016. Münchener Rückversicherungs-Gesellschaft (Münich Re), 2016. NatCatSERVICE: Loss events worldwide 1980–2015.

# AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Climate-related Effects on the Arctic Cryosphere and Adaptation Options

Reston, VA, USA, 28 April 2017

## Workshop agenda

*Co-Chairs*: Morten S. Olsen (Denmark), Jim Overland (USA)

**Opening and welcome**
Lars-Otto Reiersen, AMAP Executive Secretary

**Context of the workshop: Research needs defined for EU-PolarNet work**
Nicole Biebow, AWI, Project Manager EU-PolarNet

**Aims and outcome of the workshop**
Janet Pawlak, AMAP Secretariat – Rapporteur

**Summary of research needs on climate-related effects on the Arctic cryosphere from the AMAP conference**
Ross Brown, Environment Canada

**Research needs on climate-related effects on the Arctic cryosphere: marine systems**
David Barber, University of Manitoba, Winnipeg

**Research needs on climate-related effects on the Arctic cryosphere: terrestrial systems**
Vladimir Romanovsky, University of Alaska Fairbanks

**Summary of research needs on adaptation options for climate-related effects on the Arctic cryosphere from the AMAP conference**
Larry Hinzman, University of Alaska Fairbanks

**Research needs on adaptation options for climate-related effects on the Arctic cryosphere: risks to food security and human health**
Jim Berner, Alaska Native Tribal Health Consortium

**Research needs on adaptation options for climate-related effects on the Arctic cryosphere: natural hazards**
Katia Kontar, University of Alaska Fairbanks

**Panel discussion – Research needs for Arctic climate-related effects**

**Final remarks and closing of meeting**

# Workshop participants

| Name | Institute |
|---|---|
| Sarah Abdelrahim | Office of Policy Analysis, U.S. Department of the Interior, Washington D.C., USA |
| Thomas W. Armstrong | Madison River Group, Inc., Ashburn, VA, USA |
| Kristina Bär | Alfred Wegener Institute, Bremerhaven, Germany |
| David Barber* | University of Manitoba, Faculty of Environment, Earth, and Resources, Winnipeg, MB, Canada |
| Carolina Behe | Inuit Circumpolar Council Alaska, Anchorage, AK, USA |
| James E. Berner* | Alaska Native Tribal Health Consortium, Division of Community Health, Anchorage, AK, USA |
| Nicole Biebow* | Alfred Wegener Institute, Bremerhaven, Germany |
| Nathia Hass Brandtberg | Ministry of Independence, Nature, Environment and Agriculture, Nuuk, Greenland |
| Ross D. Brown* | Environment and Climate Change Canada @ Ouranos, Montréal, QC, Canada |
| Marcus Carson | Stockholm Environment Institute, Stockholm, Sweden |
| Apurva Dave | US Global Change Research Program, Washington D.C., USA |
| Bob Van Dijken | Arctic Athabaskan Council, Whitehorse, YT, Canada |
| Laura Eerkes-Medrano | University of Victoria, BC, Canada |
| Igor Eulaers | Arctic Research Centre, Aarhus University, Denmark |
| Martin Forsius | Finnish Environment Institute (SYKE), Natural Environment Centre, Helsinki, Finland |
| Jon L. Fuglestad | AMAP Secretariat, Oslo, Norway |
| Neil Gardner | DHA Health Services Researcher, Fairfax, VA, USA |
| Dwight K. Gledhill | NOAA Ocean Acidification Program, Silver Spring, MD, USA |
| Patrick Gruben | Inuvialuit Game Council (IGC), Inuvik, NT, Canada |
| Ramon Guardans | Advisor, MAGRAMA, Madrid, Spain |
| Peter Harris | GRID-Arendal, Arendal, Norway |
| Thomas W. Hennessy | Arctic Investigations Program, National Center for Emerging and Zoonotic Infectious Diseases, U.S. Centers for Disease Control and Prevention (CDC), Anchorage, AK, USA |
| Larry D. Hinzman* | Civil and Environmental Engineering, University of Alaska Fairbanks, AK, USA |
| Lawrence Hislop | Climate and Cryosphere Project, Tromsø, Norway |
| Katia Kontar* | International Arctic Research Center (IARC), University of Alaska Fairbanks, AK, USA |
| Marianne Kroglund | Norwegian Environment Agency, Oslo, Norway |
| Eva Kruemmel | Inuit Circumpolar Council (ICC), Ottawa, ON, Canada |
| Jan Rene Larsen | AMAP Secretariat, Oslo, Norway |

| Name | Institute |
| --- | --- |
| Kirsti Latola | University of the Arctic / University of Oulu, Finland |
| Kathy Law | LATMOS-CNRS, Paris, France |
| Melanie Lemire | CHU de Quebec Research Center, Québec, QC, Canada |
| Ingunn Lindeman | Norwegian Environment Agency, Oslo, Norway |
| Fred Lipschultz | US Global Change Research Program, Washington D.C., USA |
| Stella Melo | Meteorological Research Division, Environment and Climate Change Canada, Toronto, ON, Canada |
| Julie Morris | US Global Change Research Program, Washington D.C., USA |
| Anders Mosbech | Aarhus University, Aarhus, Denmark |
| Morten S. Olsen<br>Co-Chair | Danish Ministry of Energy, Utilities and Climate, Danish Energy Agency, Copenhagen, Denmark |
| James E. Overland<br>Co-Chair | NOAA Pacific Marine Environmental Laboratory (NOAA/PMEL), Seattle, WA, USA |
| Santosh Panda | University of Alaska Fairbanks, AK, USA |
| Janet F. Pawlak | AMAP Secretariat, Oslo, Norway |
| Stacy Vander Pol | National Institute of Standards and Technology, Hollings Marine Laboratory, Gaithersburg, MD, USA |
| Judith Ramos | University of Alaska Fairbanks, AK, USA |
| Arja Rautio | University of Oulu, Oulu, Finland |
| Lars-Otto Reiersen | AMAP Secretariat, Oslo, Norway |
| Robert Rich | Arctic Research Consortium of the U.S., Fairbanks, AK, USA |
| Vladimir Romanovsky* | University of Alaska Fairbanks, AK, USA |
| Seth Sivinski | North Star Group, USA |
| Norman Snow | Inuvialuit Game Council (IGC), Inuvik, NT, Canada |
| Martin Sommerkorn | WWF Arctic Programme, Oslo, Norway |
| Frits Steenhuisen | Arctic Centre, University of Groningen, The Netherlands |
| Vito Vitale | Institute of Atmospheric Sciences and Climate (ISAC) Italian National Research Council (CNR), Bologna, Italy |
| Katherine Weingartner | US Global Change Research Program, Washington D.C., USA |
| Simon Wilson | AMAP Secretariat, Oslo, Norway |
| Yulia Zaika | The Faculty of Geography Lomonosov Moscow State University, Kirovsk, Russia |

* Workshop presenter and panelist.


*Kettle hole, southern Iceland ©Moyan Brenn*

PART D

# AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Arctic Biology and Terrestrial Ecosystems

Rovaniemi, Finland, 12 October 2018

## Contents

# Executive Summary

Based on the presentations and discussions at the AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Arctic Biology and Terrestrial Ecosystems, a number of priority research needs were identified.

To obtain a more balanced approach to knowledge production for biodiversity stewardship, there is a need to ***determine the relevant approaches to understand biodiversity-related issues***. Ecological frameworks focus on ecological components and external drivers, while socio-ecological frameworks also include social and economic factors. A framework is required to decide when and where each approach is relevant and to find new approaches that cut across disciplines to advance our ability to tailor research to stakeholder needs. There is also a need to develop a better understanding of how stakeholders conceive Arctic systems and futures. This will inform research and monitoring needs for decision-making and stewardship. Key objectives for future research should include an evaluation of both socio-economic and biophysical drivers of change. Systematic approaches are needed to evaluate gaps and biases in current research relative to the different needs of stakeholders, taking into account the multiple objectives of these stakeholders. Future monitoring and research assessments should improve translation of scientific output to policy-maker needs; this implies dialogue and a need to know their requirements.

Given the strong spatial biases in Arctic biodiversity research, there is a need for ***in-depth systematic analyses of gaps and biases in current research*** and syntheses. While large, long-term research initiatives are crucial for understanding complex Arctic systems that can only be elucidated from such research programs, most understanding of the Arctic derives from very few sites. Smaller local initiatives are needed to understand Arctic biodiversity change in a greater variety of contexts to deal with the context-dependency of many ecological phenomena. Many processes in Arctic ecosystems are slow, inherently variable, and respond to climate change with time-lags. Understanding these ecosystems requires long-term data to distinguish natural variability from real change. Combined time series are needed to associate possible causes with consequences.

***Ecosystem-based research*** that focuses on ***species interactions within food webs***, together with climate impact pathways to understand the impact of climate change on terrestrial ecosystems, is important for devising informed management strategies in a changing environment. These management strategies are important in relation to key species that are either harvested, providing important living resources such as reindeer to humans, or that provide crucial resources (habitats, food) for harvested animals. Conceptual models are needed to determine the types of anticipated climate impact pathways to be able to formulate more focused hypotheses and research efforts.

To better predict the impacts of climate change, there is a need to ***identify species that are vulnerable to climate change using species traits***. There is a large knowledge gap regarding potential invasive species and how invasions can be prevented or mitigated. There is also poor knowledge about temporal and spatial variability in food-web processes and the predictability of such variability.

There is ***need for a mechanistic understanding of ecological properties and processes*** to provide a better understanding of the linkages between aquatic and terrestrial ecosystems; this should enable greater insight into ongoing and predicted change in Arctic landscapes. This includes a need to study climate-induced effects on regime shifts in aquatic ecosystems and food webs to better understand impacts on the productivity of these ecosystems and the ecosystem services they supply.

There is a critical requirement for ***infrastructure for long-term monitoring*** and coordination between smaller research and monitoring initiatives in the Arctic as well as appropriate sharing of data and information.

Across scientific practice, there is a need for ***harmonizing sampling methods and taxonomic nomenclature*** as well as an intercalibration of methods for use in monitoring freshwater and terrestrial ecosystems. Challenges in relation to monitoring efforts include different monitoring standards between countries, large gaps in geographical coverage of monitoring efforts, and differences in taxonomic lists and misidentification of specimens. There is a very strong need for common standards for methods and taxonomy. Currently it takes a great deal of time to harmonize data sets, given the lack of such standards. Beyond harmonized scientific data sets, an important consideration is how to expand the scope of monitoring to better include Indigenous knowledge and community-based monitoring; finding appropriate methods of co-production with science that are appropriate to different world views remains an ongoing challenge.

There is need to develop ***better insight into the taxonomy and biodiversity of Arctic freshwaters*** that can be used to identify new indicators of change and new tools for the assessment of the ecological status of Arctic aquatic ecosystems according to the EU Water Framework Directive. In addition, relevant, accurate and statistically sound indicators of ecosystem services that can be incorporated into assessment criteria need to be developed.

A strategic goal of future biodiversity monitoring in Arctic freshwaters should be ***harmonization of efforts among Arctic countries to obtain adequate sampling across representative ecoregions*** that will support the detection of spatial and temporal trends. Efforts should be made to understand how landscape modifications affect the biological assemblages of lakes and rivers and key ecosystem services such as productivity. Biodiversity trends must be related better to the underlying drivers of ecological patterns. Further development of DNA-barcoding techniques can help to provide better estimates of the species richness of complex groups that play key roles in Arctic freshwater ecosystems. Arctic countries should put these and other important research questions high on their agenda. An important way forward will be the development of new sensors and more automated technology to collect relevant data.

***Access to data that are of high quality and inclusive is crucial for future assessments*** of change in Arctic ecosystems. Arctic countries should develop joint efforts to secure existing monitoring efforts and expand them to cover the entire circumpolar region. Consistency in the funding of long-term ecological research and monitoring is imperative. Existing Arctic networks, such as INTERACT, could play a key role in monitoring and the collection of background information using various sensors and remote-sensing approaches. The participation of Indigenous Peoples' organizations and inclusion of their knowledge of the environment are important to create a richer understanding of Arctic ecosystems. This requires effective mechanisms that are inclusive from the outset and long-term funding for knowledge co-production. Citizen science and community-based monitoring through engagement of people that live in the Arctic should be encouraged.

There is a clear requirement for ***better storage of data and better data structures***. There are large amounts of data, but data quality and data structures are very diverse, making it difficult to assess the data; funding is needed to develop an appropriate data management structure. Arctic countries should invest in the establishment of joint database infrastructure for research and monitoring data. A large amount of data have already been collected on Arctic biota and ecosystems and it is important to make full of use these data. Arctic countries should make efforts to document and preserve data from short-term research projects, research expeditions, industrial, university and government programs. Considering the rapid changes occurring in Arctic ecosystems, there is an urgent need for Arctic countries to continue building baseline databases on ecosystem parameters.

There is a clear ***need for early inclusion of Indigenous People and Indigenous communities in the research process***. The incorporation of Indigenous knowledge into research must occur in a participatory process, involving Indigenous participants from the initial formulation of projects. Bringing Indigenous knowledge and traditional knowledge together with academic science can develop a more sufficient and deep cross-disciplinary understanding. Mechanisms need to be developed for full and effective participation in research formulation and implementation and to strengthen the Indigenous Peoples' institutions so that there is local capacity for such participation. Systematic ways are needed to address this cooperation. Research funding schemes may need to have greater focus on creating an effective process for cooperation between Indigenous organizations and knowledge-holders and scientists rather than research outcomes in their initial stages to support effective participation and address stakeholder needs. The results of research must be communicated to the Indigenous communities so that they can use it effectively.

A ***better understanding of the ecological effects of the fragmentation*** of terrestrial Arctic ecosystems along the Arctic coastline and on islands is important for the ability to manage and utilize Arctic ecosystems in the face of the challenges posed by climate change. Among knowledge needed on this issue are: quantification of how much more fragmentation will occur under climate change; an understanding of the ecological drivers of range shifts; a better understanding of ecological interactions and ecosystem dynamics; and better knowledge on aquatic environments.

***New approaches for long-term ecological research and monitoring*** should be implemented, including DNA-barcoding and environmental DNA (eDNA) for better taxonomic resolution of complex groups that are key components of food webs in Arctic aquatic ecosystems. Better knowledge of these taxonomic groups could lead to greater insight into the biodiversity of these ecosystems and the development of assessment tools. Better use of sensors and remote sensing for the quantification of ecological change in Arctic landscapes is also needed. The use of remote sensing should be examined as a possible tool to increase monitoring intensity and geographical coverage. Developing new methodologies is important; however, the use of new methods should not compromise long-term data sets.

***Cooperation is essential in all contexts***: between scientists and local people; between terrestrial and freshwater studies; and together with Indigenous Peoples. Cooperation is also necessary concerning methods and how the data are stored and used.

Collaboration on large spatial scale assessments of functions and processes requires cooperation with people across the Arctic and with other countries. Harmonization is an important function in large-scale cooperation. More cooperation between European countries and North America is very much desired, but funding remains a problem for this cooperation. However, new EU research calls are bringing greater possibilities for trans-Atlantic cooperation in research activities. The difficulty of participation of Russian scientists in much of the work in the Arctic was considered regrettable, given that roughly half of the Arctic is in Russia.

## D1 Background

There are many challenges affecting Arctic terrestrial and freshwater ecosystems, from the rapidly changing climate to the increase in human activities. Challenges to Arctic terrestrial ecosystems affect their living resources, including reindeer and other subsistence animals and plants, as well as their vulnerability to increased human activities and climate change. The influence of ongoing changes in the cryosphere on Arctic species composition and diversity and on terrestrial and freshwater ecosystems also creates feedbacks that affect the climate system.

The Arctic Monitoring and Assessment Programme (AMAP), as a partner in the Horizon 2020 coordination and support action EU-PolarNet, is responsible for promoting trans-Atlantic research activities between EU countries and the USA and Canada and, as one aspect of this, to hold international stakeholder workshops to determine common research needs that can be provided as input to the central EU-PolarNet requirement, namely, to develop an Integrated European Polar Research Programme together with an implementation plan. An important aspect of EU-PolarNet is 'connecting science with society', under which dialogue and cooperation with relevant Arctic stakeholders will ensure their input to the formulation of this research program. The AMAP / EU-PolarNet Stakeholder Workshop on Research Needs on Arctic Biology and Terrestrial Ecosystems is the fourth and final AMAP-organized stakeholder workshop to identify and formulate key Arctic research needs over the five years of the project. The central theme of this workshop is research needs to obtain a better understanding of Arctic terrestrial ecosystems and living resources and their vulnerability to increased human activities, Arctic freshwater and coastal ecosystem changes and their impacts on biota, and the influence of climate-related changes on Arctic flora and fauna.

The stakeholder workshop was held in association with the second Arctic Biodiversity Congress, hosted and arranged by the Conservation of Arctic Flora and Fauna (CAFF), a working group of the Arctic Council, and the Finnish Ministry of the Environment, that was held in Rovaniemi, Finland from 9 to 12 October 2018. The AMAP / EU-PolarNet workshop was held on the morning of 12 October and drew on the summaries of scientific input and research ideas arising from the Congress, as well as targeted keynote presentations to focus discussions at the workshop.

The format of the workshop, after the introductory presentations setting the background and aims, comprised presentations by several experts from around the Circumpolar North on specific themes followed by discussion by the participants of the ideas presented and identification of research needs requiring further work. The workshop participants, as a group, then considered all material presented to identify key themes and approaches.

## D2 Opening and welcome

The Workshop was co-chaired by Nicole Biebow (Project Manager of EU-PolarNet, Alfred Wegener Institute for Polar and Marine Research, Germany), Joseph Culp (Environment and Climate Change Canada), and Willem Goedkoop (Swedish University of Agricultural Sciences). Nicole Biebow opened the meeting and welcomed the participants. Ingunn Lindeman, Norwegian Head of Delegation to AMAP, welcomed the participants to the workshop on behalf of AMAP.

## D3 Context of the workshop: Research needs for EU-PolarNet work

Nicole Biebow presented a brief overview of the background to the workshop. The European Commission established the five-year coordination and support action 'EU-PolarNet – Connecting Science with Society' to maintain an ongoing dialogue with the EC on polar issues and to develop an Integrated European Polar Research Programme that should be co-designed with all relevant stakeholders. EU-PolarNet should also design a resource-oriented European infrastructure access and usage plan as well as improve and strengthen international cooperation and implement the Transatlantic Research Alliance.

EU-PolarNet is the largest consortium of expertise and infrastructure for polar research. The consortium consists of 22 partners representing 17 European countries and all major research institutions conducting research in polar areas; it has 24 international cooperation partners. EU-PolarNet has established an ongoing dialogue between policy-makers, business and industry leaders, local communities and scientists to increase mutual understanding and identify new ways of working that will deliver economic and societal benefits. The results of this dialogue will be brought together in a plan for an Integrated European Research Programme for the Antarctic and the Arctic. This is being co-designed with all relevant stakeholders and coordinated with the activities of many other polar research nations beyond Europe, including Canada and the United States, with which consortium partners already have productive links. The AMAP / EU-PolarNet Stakeholder Workshop on Research Needs on Arctic Biology and Terrestrial Ecosystems is one important step in obtaining input from researchers and stakeholders for the Integrated European Polar Research Programme.

As a first step in the development of an Integrated Polar Research Programme co-designed with relevant stakeholders, EU-PolarNet reviewed nearly 150 documents from all over the world to determine current polar research activities and priorities. This review identified ten research themes with key questions and related societal relevance. The resulting report served as a basis for a broad online consultation to identify research priorities for the polar regions according to a set of five overarching themes; this provided over 500 responses from 36 countries and a range of stakeholders.

All of the above material was used as a basis for the preparation of five White Papers that address urgent polar research questions; these White Papers were co-created by 50 stakeholders and scientific experts during a five-day meeting that also included representatives of business and Arctic Indigenous Peoples. Policy-maker summaries of these five White Papers have been distributed to the European Parliament, and full versions will be ready in due course.

The next major activity will be the development of the Integrated European Polar Research Programme; this workshop will provide stakeholder and expert input to this deliverable. Further information is available at www.eu-polarnet.eu.

In conclusion, Nicole Biebow described the EU Arctic Cluster, which is a network of currently funded Horizon 2020 Arctic projects and which merges the most up-to-date findings on Arctic change and its global implications (www.eu-arcticcluster.eu).

## D4 Aims and outcome of the workshop

The workshop organizer and meeting rapporteur, Janet Pawlak, AMAP Deputy Executive Secretary, emphasized the importance of this workshop as one of the stakeholder contributions to the further development of prioritized objectives for Arctic research and ultimately the Integrated European Research Programme for the Arctic. As Arctic biology and terrestrial ecosystems are only part of many research topics for the Arctic, this workshop should aim to identify the most important research needs on this topic. These research needs will be included in the report she will prepare, based on the presentations and discussions at the workshop, for submission to EU-PolarNet as a stakeholder contribution on Arctic biology and terrestrial ecosystems. The report is also a project deliverable to the European Commission for its information and use.

## D5 Summary of research needs on terrestrial ecosystems and climate-related ecosystem changes from the Arctic Biodiversity Congress

Eefje de Goede, Leiden University, The Netherlands, presented an overview of research needs articulated during the various sessions of the Arctic Biodiversity Congress related to terrestrial ecosystems and climate-related impacts on those ecosystems. She stated that research needs had been expressed on a very wide and diverse range of topics covering many types of vegetation and animals. These include:

1. There is a need to understand the influence of trampling of Arctic soils, especially permafrost soils, by reindeer and other large herbivores and the potential that this may reduce thawing.
2. There is a need to understand the influence of herbivore grazing on vegetation, including on plant heterogeneity, shrubification and soil carbon loss/sequestration; this could potentially be used, among others, to determine whether grazing management might be used to mitigate effects of climate warming in relation to both soil carbon losses and shrubification.
3. There is a need to better understand the various factors influencing the distribution of plant species in the Arctic, including the influence of snow cover or lack thereof on biodiversity changes, the influence of geomorphological disturbances and cryogenic processes on vegetation biomass and biodiversity, the influence of changes in water availability on vegetation patterns and the effects of extreme weather events.
4. To better predict the impacts of climate change, there is a need to identify species that are vulnerable to climate change using species traits. There is a large knowledge gap regarding potential invasive species and how invasions can be prevented or mitigated.
5. There are a number of challenges in relation to monitoring efforts, including different monitoring standards between countries, large gaps in geographical coverage of monitoring efforts, and differences in taxonomic lists and misidentification of specimens. Developing new methodologies is important, for example, the use of environmental DNA (eDNA) sequencing to monitor for new species. However, the use of new methods should not compromise long-term data sets.
6. The use of remote sensing should be examined as a possible useful tool to increase monitoring intensity and geographical coverage.
7. Simple tools need to be developed that can be used for management and conservation, such as a tool to rank sensitivity and vulnerability of Arctic coasts for oil spill response planning, and a tool to rank areas according to their conservation value.

## D6 Research needs on terrestrial ecosystems and their living resources; impact of climate change

Eeva Soininen, University of Tromsø, Norway, stated that the Climate-Ecological Observatory for Arctic Tundra (COAT) in Norway is investigating the impacts of climate change on Arctic ecosystems. This work has shown that warm, rainy winters have large effects on High Arctic ecosystems. Three major herbivores, the reindeer, ptarmigan and vole, have high winter mortality because they cannot access food when rain-on-snow events occur and freeze the surface. These events synchronize the population dynamics across an entire community of vertebrate herbivores, and changes in prey availability also affect the fox population dynamics the following year. Thus, climate change often impacts Arctic terrestrial ecosystems indirectly through the food web: an impact on one organism in turn impacts other organisms, occurring simultaneously on many species and their ecological functions.

Accordingly, research on climate change impacts on Arctic terrestrial ecosystems should focus on food web ecology, studying how climate change impacts propagate or even accentuate through food webs and trophic interactions. While the food webs are complex, certain species or groups of functionally similar species (functional groups) have key roles in tundra ecosystems. Such species include geese and ungulates like reindeer, whose browsing modifies vegetation patterns and is central to shrub distribution. Many such key species and groups are also either harvested, providing important living resources to humans, or they provide crucial resources (habitats, food) for harvested animals. An example from the Low Arctic illustrates the complexity of food webs (Figure D1).

To understand the impacts of climate change on the system, it is helpful to determine what should be studied, and target closely interacting parts of the food web. The selected targets in

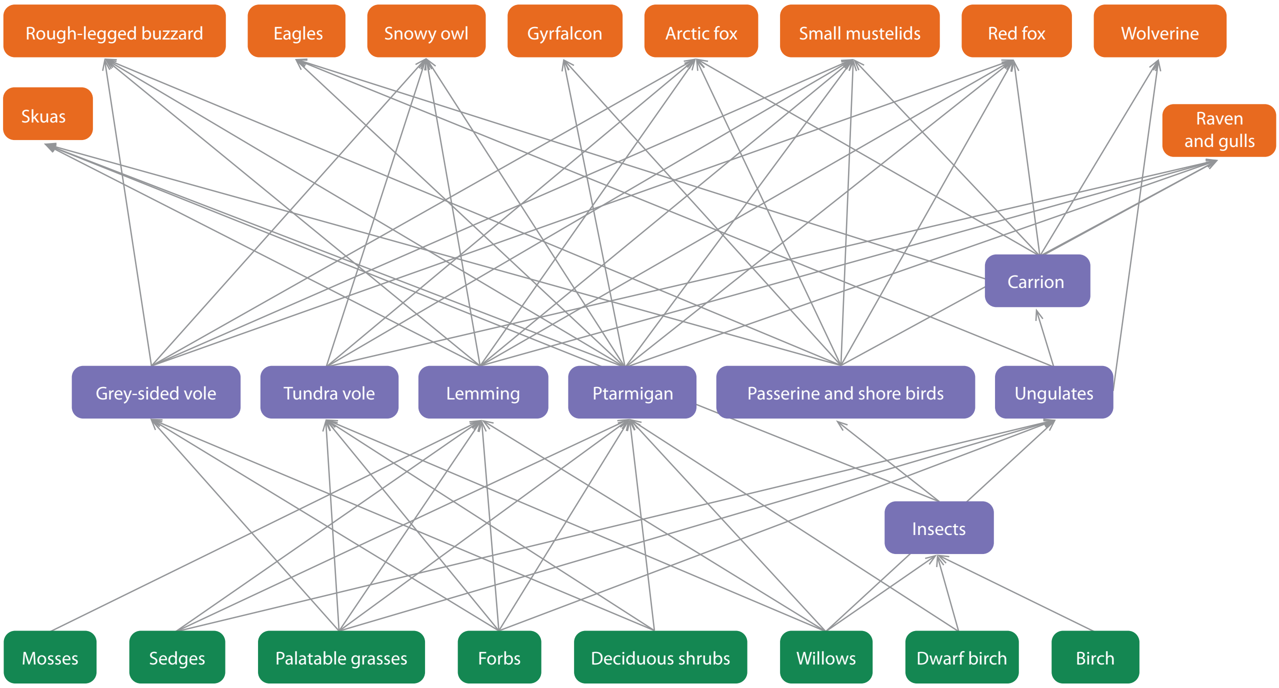


Figure D1 Simplified diagram of a Low Arctic food web, Varanger, Norway. Source: Climate-ecological Observatory for Arctic Tundra (COAT), https://www.coat.no

the food web could be harvested species or species with rapid responses to climate change. The latter are useful to determine the immediate responses of an ecosystem to climate change. For example, reindeer play a central role both as a resource to humans and as modifiers of the ecosystem; we need to conceptualize what we know about climate impacts on them, both directly and indirectly. Conceptual models that describe anticipated climate impact pathways on targeted parts of food webs are thus an important tool to formulate more focused hypotheses and to focus research efforts. These models also indicate the state of knowledge on the subject, the gaps that require study, and impact pathways other than climate (such as management effects).

Thus, ecosystem-based research that focuses on species interactions within food webs, together with climate impact pathways, is important for devising informed management strategies in a changing environment. Furthermore, many processes in Arctic ecosystems are slow, inherently variable with multi-annual dynamics, and respond to climate change with time-lags. Distinguishing natural variability from real change (e.g., trends caused by climate change) therefore requires long-term data collection. Long-term research is thus central for understanding and effective management of Arctic ecosystems.

To associate possible causes with consequences, time series of the different ecosystem components need to be collected in a combined manner. Eeva Soininen exemplified the complexity of data requirements with a time series of population dynamics of Svalbard ptarmigan (a small game bird species). The species population density had an apparent decrease until 2010, but has thereafter increased (see Figure D2). To address causes of these changes, time series on several interacting ecosystem components would be required. These include the availability of food species for ptarmigan, predation, hunting, and the climate. Collecting these types of data with a common study design that permits analysis of these variables together is major effort, particularly as these different types of data would all need to be collected at the ptarmigan monitoring sites. Nonetheless, this is the core of the concept 'ecosystem-based research', namely, a combined data collection system on several interacting species, instead of separate research programs on different species.

These difficulties are one reason why ecosystem-based research is rare, particularly in the Arctic. For example, a review of 49 monitoring programs on Arctic lemmings showed that only 21 of them monitored abiotic conditions annually. Thus, as valuable as it would be, the food-web approach represents a major effort, requiring collaboration among many scientific disciplines, and is also difficult to obtain funding for, particularly as funding is needed for a period longer than most funding programs offer. And finally, on top of this, such studies do not produce high-impact publications quickly and thus are not attractive to young scientists.


Figure D2 Development of the Svalbard rock ptarmigan population over a 17-year period. Estimates of male density are based on annual repeated point-transect surveys of territorial males during spring. Source: Soininen et al. (2016).

Eeva Soininen stated that these types of study have been undertaken at the Climate-Ecological Observatory for Arctic Tundra (COAT), to attempt to move from a food web diagram to conceptual models of climate impact pathways. Among the lessons learned from this work are that there is poor understanding of winter ecology and processes because most field work is conducted during the summer. There is also poor knowledge about temporal and spatial variability in food-web processes and the predictability of such variability. The issue of the scale of the data collection is also significant. An important way forward will be the development of new sensors and more automated technology to collect relevant data.

In the discussion of this presentation, it was noted that these problems in understanding changes in terrestrial ecosystems are equally encountered in the study of freshwater ecosystems. It could be very beneficial to pool efforts in the freshwater, coastal and terrestrial zones, using key sites with a history of measurements to obtain a more complete picture of ecosystem changes.

## D7 Research needs on Arctic biology and biodiversity

Helen Wheeler, Anglia Ruskin University, UK, stated that a key concern of Arctic biodiversity research is to provide evidence to inform stewardship of the Arctic into the next century (Chapin et al., 2015). This concerns the dual objectives of protecting biodiversity and meeting human needs. In the Arctic, climate-induced changes in the cryosphere link rapid climatic, ecological, social and economic change; this creates critical new challenges for biodiversity monitoring and research. Evaluating the needs for monitoring and research in this context represents a major challenge; rapidly changing conditions set the stage for new or transformed drivers of change, increased potential for driver interactions and a wider range of actors influencing decision-making. This increases the risks that certain stakeholder needs remain unrepresented or important drivers of change remain unaddressed.

Large-scale information and knowledge synthesis has increasing influence on policy- and decision-making. Synthesis can occur formally by gathering and analyzing data or informally from the impression gained from a body of knowledge. Uneven availability, accessibility and use of knowledge during synthesis are pervasive across a number of different areas, from big data analyses to whether Indigenous and local knowledge is incorporated into decision-making (Leonelli et al., 2017). Biases can be taxonomic, spatial, conceptual or at a more fundamental level of discourse. These affect the critical issue of whether the knowledge base reflects a fair, inclusive representation of the concerns of the stakeholders implicated in a decision and an accurate representation of the situation assessed. Deficiencies in how information and knowledge are produced, recorded and synthesized lead to poor decision-making and discontent and non-cooperation of stakeholders.

Research and monitoring concerning biodiversity have multiple objectives, which are often loosely defined and differ between different actors and stakeholders who produce, process and use knowledge and information. A first step to guiding future Arctic biodiversity research is developing a better understanding of how stakeholders conceive systems and Arctic futures. This will inform research and monitoring needs for decision-making and stewardship. Where the production and use of information and knowledge appears biased toward the concerns of certain stakeholders, conflicts may emerge as well as inequities in decision-making.

Accordingly, the following are key objectives for future research that reflects the issue of unexplored gaps in research and monitoring:

- Systematic approaches to evaluating gaps and biases in current research relative to the different needs of stakeholders (Indigenous and local communities, decision-makers, scientists), taking into account the multiple objectives of these stakeholders.
- Evaluation of both socio-economic and biophysical drivers of change.
- Assessment of drivers of context-dependency in ecological response to drivers of change.

Biases in the relative representation of different drivers of change, sources of knowledge and system components can greatly affect the perception of how Arctic biodiversity-related systems function. A recent study highlights how much of our understanding of ecological processes in the Arctic emerges from a few dominant research sites (Metcalfe et al., 2018). Increasingly, studies of Arctic biodiversity demonstrate that ecological processes are highly context-dependent (Chamberlain et al., 2014; Wheeler et al., 2018); therefore, generating our understanding of biodiversity change from these sites may risk a very unrepresentative and biased view. While opinions on gaps and biases may provide useful insights, these cannot be evaluated without structured and systematic approaches to assess biases. The predominance of only a few sites in research literature highlights the need not only to fund these major research initiatives to understand complex relationships that can only be elucidated from long-term and expansive research programs, but also to widen the number of locations and contexts where studies occur to deal with the currently unaddressed context-dependency of many ecological phenomena.

In addition to emerging from only a few sites, the disciplinary framework that we use to conduct biodiversity research also has an effect on what components of systems are studied. While social science tends to focus on broader socio-ecological systems that incorporate governance systems, human actors and socio-economic and political settings, ecological approaches are largely more focused on impacts of biophysical change (such as changes in climate and habitat). Currently, ecological approaches dominate the research literature and this can affect the drivers of change that are included in research. In addition, the mode of local participation is influenced by the choice of approach; these factors in turn all affect current research foci and biases (Figure D3).

Without a full evaluation of these biases, misconceptions may develop during both formal and informal syntheses. How we view systems can affect the inclusion of different types of information and knowledge in our analysis of biodiversity-related systems. Ecological frameworks focus on ecological components and influences or external drivers, while socio-ecological frameworks include social and economic factors including governance structures, different actors and cultures

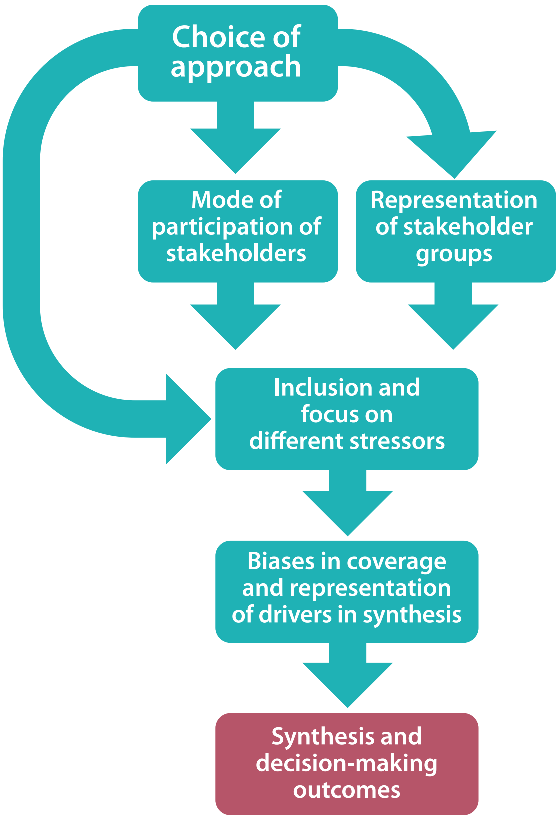


Figure D3 Selected drivers of research biases.

within their system conception. While both approaches have been used to understand biodiversity-related issues, these disciplines remain quite distinct. Deciding when and where each approach is relevant is key to a more balanced approach to information and knowledge production for biodiversity stewardship and finding new approaches that cut across disciplines could greatly advance our ability to tailor our research to stakeholder needs.

This includes ensuring that the evaluation of the impacts of drivers of change is not limited to drivers and responses that are simple to enumerate. This may be a particular concern in relation to digital technologies (e.g., satellite imagery). Novel technologies can be seen as both a risk and an opportunity. In addition to making use of these technologies, we must consider what drivers may be missed owing to incompatibility with these analytical frameworks. Greater uptake of digital technologies in research may, for example, risk a lack of focus on social drivers of biodiversity change as these are more challenging to enumerate, particularly with these methods. Similarly, as upscaling becomes an increasingly prevalent aim it is important not to undervalue the local studies of biodiversity and the investigation of context-dependency.

A core objective of current research is to work in a more acceptable and effective way with Indigenous communities. This moves beyond simply asking Indigenous people to provide data within scientific frameworks. There are increasing calls for the incorporation of Indigenous knowledge into research to be a participatory process, which involves Indigenous participants from the initial formulation of projects. This poses particular challenges within current funding systems where successful proposals generally require well-defined project outcomes from the outset. This can result in projects that are initiated by researchers and then attempt to involve communities at later stages, which may result in projects less effectively representing Indigenous needs and power imbalances between participants. One potential solution may be funding schemes that have greater focus on process rather than outcome in their initial stages, given that an effective participation and engagement process and team structure are crucial to addressing stakeholder needs. Another consideration is the need to strengthen Indigenous institutions so that there is local capacity for such participation, which can often be a barrier to knowledge co-production. Finally, many community-driven monitoring programs, which often include Indigenous participation, are limited by a lack of clear understanding of the needs of decision- and policy-makers; greater focus on integrating each of these actors in research processes may potentially alleviate this issue.

In summary, given that strong spatial biases in Arctic biodiversity research have been identified, there is a need for in-depth systematic analyses of gaps and biases in current research and syntheses. While new technologies have the potential to strengthen some areas of Arctic research, evaluation of the limitations of these approaches is also needed, so that these gaps can be filled; these gaps often concern more socio-ecological aspects of the systems. Similarly, while large and long-term research initiatives are important for understanding complex Arctic systems, most of our understanding of the Arctic comes from very few sites, highlighting the value of also promoting smaller local initiatives to understand Arctic biodiversity change in a greater variety of contexts. Finally, as the need to involve Indigenous Peoples in Arctic research is increasingly affirmed, there is a need to do this in a manner that is both effective and acceptable to these communities. A greater focus on setting up effective processes of participatory project development may be one route to achieve this.

## D8 Research challenges in Sápmi in the light of climate change and cumulative effects

Katarina Inga, Sámi Council, stated that reindeer herding identity is part of the Sámi culture. Sámi reindeer herding depends on weather conditions and on large areas of grazing land linked together. Climate change can cause grazing areas to be unavailable; for example, winter rain-on-snow events create an impediment for access to food for reindeer, causing problems for Sámi. In addition, a number of industrial activities that claim land area by construction or via disturbance as movements and sound, such as wind power parks, railroads, logging, mines, dogsledding and snowmobiles, impact the reindeer negatively. They also create barriers for reindeer migration to new foraging grounds. Disturbance in the grazing area can cause the reindeer to avoid good grazing grounds. For example, logged areas associated with wetlands can affect the potential to use the wetland when alternative food resources and shelter are removed. Among other impacts of climate change on Sámi communities is the problem that the ice on lakes is no longer reliable, thus limiting transportation options. There is also now a need to provide food for reindeer in the winter owing to the problems with foraging in the wild, although the latter is clearly preferable. Another problem is that the variable winter weather with wet snow causes a problem for the reindeer, as they become cold if wet snow stays on their fur. It is therefore important to have a holistic approach to the effects on grazing grounds caused by the expansion of industrial and other activities and intrusions on land areas. As such, the effects of climate change and land use activities cause a cumulative negative effect for the reindeer and Sámi reindeer herding.

Changes in nature result from a combination of external factors including climate change and ongoing uses of the land. It is import to understand the historical and current uses of the land in order to more clearly identify the effects of climate change and land use developments. Indigenous knowledge is based on the combination of social and natural aspects and has been tested over generations. Accordingly, Indigenous traditional knowledge provides a holistic overview in both space and time, compared to academic science where the research often is limited to local effects during a specific time period. Bringing together these two sources of knowledge can develop a more sufficient and deep understanding. Hence, cross-disciplinary sharing of knowledge early in the research planning is crucial. However, to be able to both conduct relevant research and redistribute the research findings to those to whom it concerns, there is a need to organize the system of how knowledge is shared and owned.

Katarina Inga stated that it is important for Sámi society to participate in research in a relevant way; Sámi need to strengthen their own institutions so that they can participate appropriately. It is important that the results of research be communicated to the Sámi communities so that they can also use it. Indigenous knowledge is often silent; it cannot be read because is arises from experience. Therefore, Sámi institutions are needed to gather this knowledge so that it can be communicated and used by a wider audience.

In the discussion of this presentation, the importance was emphasized of involving Indigenous people in the development of new research; their views of what they would like to know are important. However, past experience has shown that, despite a law requiring consultation with Sámi people on new industrial activities, their input has generally been ignored.

It was considered that reaching out to Indigenous people early in the process of deciding a research project is very important. The local people understand their ecosystems and may know a better place to conduct the work. They also know how to address specific needs, such as the placement of a weather station for the project. Early communication is important for both sides.

It was reported that in Canada, territorial programs require that a plan for communication with local people be built into the overall research project plan. In the Northwest Territories, social scientists are being used to link with local communities before the start of the project. This approach was considered to be an excellent example for ensuring that local communities are appropriately involved at the beginning of the planning.

Another issue is evaluating the impact of the early inclusion of Indigenous and local communities and how these communities use the ultimate results of the project.

It was noted that some of the new EU funding calls require communication and full involvement with European Indigenous communities, including that they can be a full partner from the beginning. EU programs also have a very large impact requirement in their projects.

## D9 Summary of research needs on Arctic biology/biodiversity and freshwater ecosystems from the Arctic Biodiversity Congress

Joseph Culp, Environment and Climate Change Canada, reported that CAFF had recently completed the first State of Arctic Freshwater Biodiversity Report (SAFBR). Freshwater ecosystems cover more than 80% of the Arctic landscape, and some of the largest deltas, rivers and wetland complexes are located in the Arctic. The assessment of biodiversity in this important area fulfilled a goal identified in the Arctic Climate Impact Assessment (ACIA, 2005) and the Arctic Biodiversity Assessment (CAFF, 2013). The SAFBR assessment used an ecosystem-based approach to identify the state, trends and causal relationships in freshwater systems using Focal Ecosystem Components (FECs) and represented the first circumpolar assessment of biological monitoring data in Arctic lakes and rivers.

The freshwater assessment report showed that Arctic freshwater biodiversity is under increasing pressure from climate change and resource development (Figure D4). The Arctic is warming more quickly than other parts of the Earth and is also subject to increasing pressure from development. Collectively, these pressures result in changes to freshwater ecosystem and habitat characteristics, changes in species composition and richness, and an altered geographical distribution of species.

Based on the experience gained in this assessment, several novel research and monitoring approaches were proposed:

- The ecoregion should guide the spatial distribution of sampling stations to improve assessments.
- There is a need for harmonizing sampling methods and taxonomic nomenclature as well as an intercalibration of methods.
- A circumpolar monitoring network should be established based on a hub-and-spoke (intensive-extensive) principle, for example, using the Canadian High Arctic Research Station (CHARS) and Zackenberg Research Station; the study design should address the Circumpolar Biodiversity Monitoring Programme (CBMP)-Freshwater Impact Hypotheses and Focal Ecosystem Components.
- Ecological functions, such as traits, key ecological processes, and microbial pathways, should be examined.

The report includes a number of recommendations for future monitoring approaches that would lead to increased capacity to monitor and detect trends in Arctic freshwaters in a coordinated way. Critical to this is the engagement of local communities and increasing monitoring efforts by including Citizen Science and Traditional Knowledge as an integral part of monitoring networks; these should be included as a component of future funding calls. Greater use of remote sensing techniques, including satellite imagery and *in situ* data sensors, is recommended to increase the spatial and temporal coverage of monitoring data. In addition, increased use of emerging technologies such as environmental DNA and bar coding methods in monitoring, for example, for diatoms and invertebrates, can facilitate more widespread assessment of taxonomic richness in the Arctic.

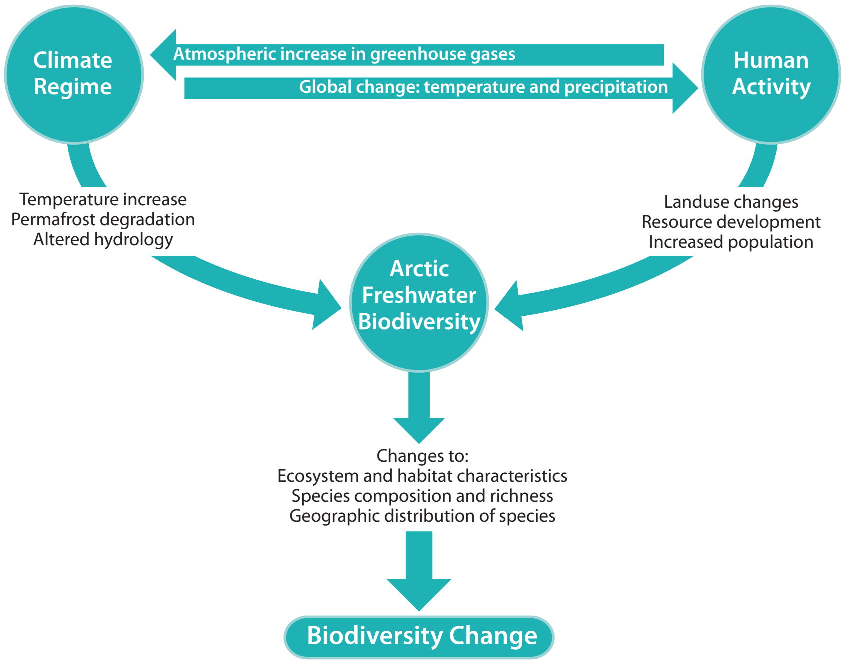


Figure D4 Pressures on Arctic freshwater biodiversity. Source: Culp et al. (2012).

Joseph Culp recommended that future monitoring and research assessments should:

- Assess spatial and temporal diversity patterns across the circumpolar region to better understand the key drivers of biodiversity change among Focal Ecosystem Components.
- Continue building the CBMP Freshwater Database; this will require a country-wise focus on data preservation from industry, academic and government programs and funding agencies should have a call for developing databases and adding older data.
- Improve translation of scientific output to policy-maker needs; this implies dialogue and a need to know their requirements.
- Consider the potential importance of phenotypic variation in conserving biodiversity (phenotype variation in species composition should be monitored).

In summary, Arctic freshwater ecosystems are threatened by climate change and human development that can affect freshwater biodiversity. Such effects will change not only the distributions and abundances of aquatic species, but also the lives of Arctic Peoples that are dependent on freshwater ecosystem services. A strategic goal of future biodiversity monitoring efforts of Arctic freshwaters should be harmonization efforts among Arctic countries with adequate sampling across representative ecoregions to support the detection of spatial and temporal trends. Biodiversity trends must also be related better to the underlying drivers of ecological patterns. Future monitoring should consider emerging approaches such as environmental DNA methods, community and citizen science efforts, and make better use of remote sensing tools. In addition, Arctic countries should make efforts to document and preserve data from short-term research projects, research expeditions, industrial, university and government programs. Considering the rapid changes occurring in Arctic ecosystems, there is an urgent need for the Arctic countries to continue building baseline databases, such as that produced by the CBMP-Freshwater of CAFF, to aid the assessment of future biodiversity change.

In the discussion of this presentation, it was noted that there are increasing demands for better storage of data and better data structures. There are large amounts of data, but data quality and data structures are very diverse, making it difficult to harmonize and combine the data for assessment. There is a need for much work and funding to develop an appropriate data management structure and to promote coordination and harmonization of data storage.

It was noted that researchers do not always consider how to have clear data in a useful form. There is a need to be able to understand the data and the quality of the data. Thus, it would be useful to work with the researchers when their data are input to a database so that the data can be understood and better used. This needs much work and much funding. Calls are needed to fund the development of databases for specific needs and uses, as well as for the long-term maintenance of those databases. It was generally agreed that as much data should be made available as possible, to stimulate the use of these data and allow a more creative approach by other users.

## D10 Research needs on Arctic freshwater systems and freshwater biology; impact of climate change

Willem Goedkoop, Swedish University of Agricultural Sciences, Uppsala, stated that lakes and rivers are mirrors of the landscape. Water quality is the chemical habitat for freshwater diversity, and is also an early warning of change. Water quality and biodiversity of lakes and rivers closely reflect catchment geology, vegetation cover and anthropogenic activities such as land-use change, industrial development, and diffuse and point-source pollution. These stressors put constraints on species assemblages and the ecosystem services they provide. For example, northern lakes are subjected to dramatic declines in nutrient concentrations as a consequence of ongoing, climate-driven shifts in large-scale catchment processes that contribute to reductions in nutrient runoff such as (1) the observed changes in tundra vegetation cover, namely, the 'Greening of the Arctic' mediated by elevated nitrogen-mineralization and increased nutrient uptake by rooted plants, (2) the more efficient trapping of phosphorus that originates from soil pH increases, and (3) low and declining trends in nitrogen deposition over the northern hemisphere. The concerted action of these large-scale changes contributes to the gradual transformation of lakes and rivers toward even more oligotrophic conditions and a further increase in the predominance of $N_2$-fixing cyanobacteria at the base of their food webs. As cyanobacteria provide a poor food source for consumers, these changes will have repercussions on grazing invertebrates and higher trophic levels, and ultimately on the food supplies for northern people, given the close linkage between aquatic and terrestrial food webs (Figure D5).

Projected climate regime alterations will change the abiotic templates of northern freshwaters, potentially causing wide-ranging ecological shifts. For example, Arctic freshwater biodiversity will respond to warming through range expansion of southern eurythermic species and losses of stenothermic species. Landscape alterations due to large-scale permafrost thawing, such as when lakes and rivers on ice are drained, will dramatically decrease the limnicity of landscapes and the connectivity of freshwaters, having major implications for biodiversity and fish production. Efforts should therefore be made to understand how landscape modifications affect the biological assemblages of lakes and rivers and key ecosystem services such as productivity. Moreover, we should improve our knowledge of the drivers of beta-diversity (e.g., nestedness and turnover) in Arctic freshwaters, as richness and biodiversity metrics disregard qualitative aspects of beta-diversity (i.e., which species) and provide poor information on biodiversity. For this, the further development of DNA-barcoding techniques can help to provide better estimates of the species richness of complex groups such as chironomids (midges) and benthic diatoms that play key roles in Arctic freshwater ecosystems. Arctic countries should put these and other important research questions high on their agenda.

Access to data of high quality is crucial for future assessments of change in Arctic ecosystems. Hence, Arctic countries should develop joint efforts to secure existing monitoring efforts and expand on them to cover the entire circumpolar region, likely according to a hub-and-spoke principle. Existing Arctic networks, such as INTERACT, could play a key role in the performance of monitoring and the collection of background information using various sensors and remote sensing approaches. Also, the engagement of Indigenous Peoples' organizations and their traditional ecological knowledge of the environment could supplement and strengthen the systematic collection of data. Arctic countries should also invest in the establishment of joint database infrastructure for research and monitoring data.

Key topics for future research programs include (in brief):

1. Mechanistic understanding of ecological properties and processes in terrestrial and aquatic ecosystems.

   – Provide a better understanding of the linkages between aquatic and terrestrial ecosystems in order to better understand ongoing and predicted change in Arctic landscapes.

   – Provide insight into the processes that affect long-term catchment hydrology and cycling of carbon, nitrogen and phosphorus (CNP) and build models that can predict future change under different climate scenarios.

   – Study climate-induced effects on regime shifts in aquatic ecosystems and the food webs of aquatic ecosystems to better understand the impact on the productivity of these ecosystems and the ecosystem services they supply.

   – Study the fate and effects of pollutants in Arctic landscapes and waterscapes.

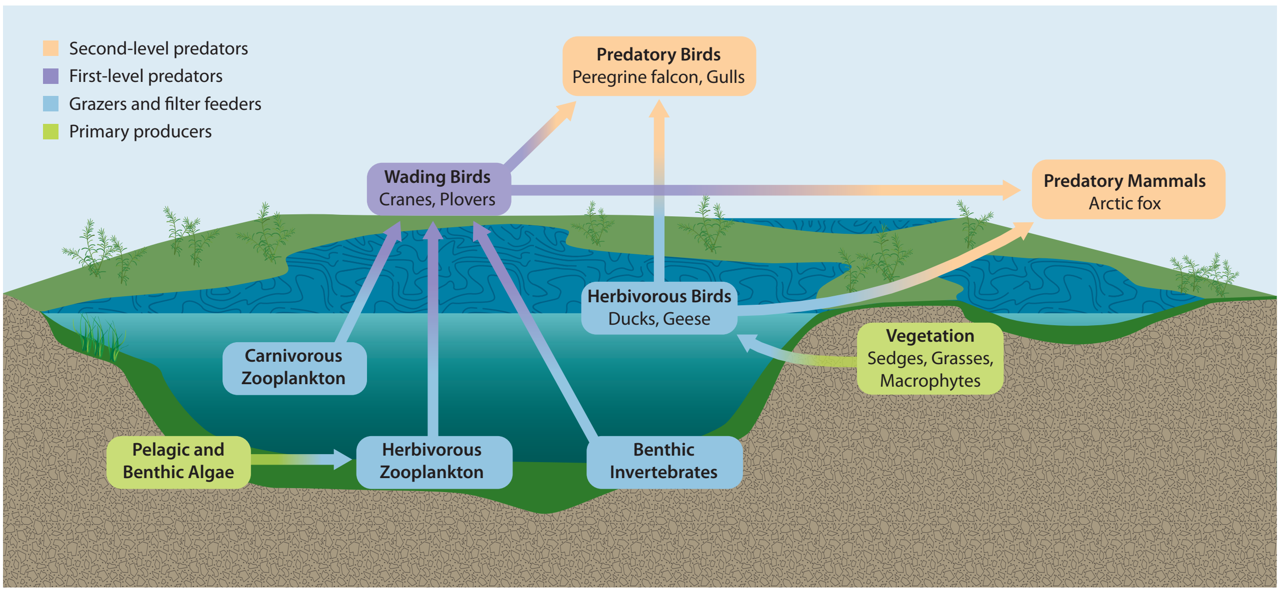


Figure D5 Aquatic and terrestrial food webs are closely linked.

2. Novel approaches for, and consistency in the funding of, long-term ecological research and monitoring.
   - Utilize DNA-barcoding and environmental DNA (eDNA) for better taxonomic resolution of complex groups that are key components of aquatic food webs in Arctic aquatic ecosystems, such as benthic algae and midges. Better knowledge of these taxonomic groups could subsequently lead to better insight into the biodiversity of these ecosystems and the development of assessment tools.
   - Promote better use of sensors and remote sensing (satellite data) for the quantification of ecological change in Arctic landscapes.
   - Stimulate citizen science through engagement of people that live in the Arctic (e.g., for reporting changes in phenology or the detection of new or invasive species).
   - Provide the infrastructure for long-term monitoring in the Arctic and open-source circumpolar databases.
3. Develop new indicators and assessment criteria for effects on species, communities, and ecosystem services and function in Arctic freshwaters.
   - Better insight into the taxonomy and biodiversity of Arctic freshwaters can be used to identify new indicators of change and new tools for the assessment of ecological status according to the EU Water Framework Directive. Current assessment tools cannot be used for the appropriate assessment of aquatic Arctic ecosystems as we (1) have poor knowledge of key organism groups, and (2) face different stressor scenarios than those for which the existing assessment tools have been developed.
   - Develop relevant, accurate and statistically sound indicators of ecosystem services that can be incorporated into assessment criteria.

In the discussion of this presentation, another stressor was noted, namely, the increase in water temperature in the past summer in high mountain lakes that had a negative impact on the fish, which need colder water. Another serious impact on Arctic freshwaters is from the discharge of mining tailings, which are very toxic, and seriously affect lakes and streams with negative consequences on ecological and societal perspectives. Controls are needed on the treatment of mining tailings, given that most often they are simply dumped into aquatic areas rather than being constrained in an artificial pond.

It was reported that Canada has a requirement for Environmental Effects Monitoring (EEM) downstream from metal mining sites and paper and pulp factories. A description of the methods for sampling and toxicity testing can be found at https://www.canada.ca/en/environment-climate-change/services/managing-pollution/environmental-effects-monitoring.html. Monitoring is also needed on effluents from oil sands production. There is much reference data for northern Canadian lakes, including on organisms, but it can be very difficult to gain access to those data.

In Greenland, there is a need to monitor discharges from mining operations and to review the data to evaluate the full area of potentially large changes in the ecosystem.

## D11 Research needs on ecological consequences of a climate-driven fragmentation of Arctic species communities

Fredrik Dalerum, University of Oviedo, Spain, stated that the increase in temperature in the Arctic with climate change will likely increase biological productivity and, therefore, also biodiversity. The terrestrial Arctic, in contrast to most other major terrestrial biomes on Earth, is a marginal biome surrounding an ocean basin. Hence, with a warming climate there is no continental land mass for Arctic species to move northward to; there will, however, be northward expansion of boreal species. Terrestrial Arctic ecosystems are fragmented by islands and rugged coastal features. Therefore, if global warming forces Arctic species further north, their distribution ranges will become increasingly more fragmented along the Arctic coastline and on Arctic islands. This process has occurred previously. Data from previous warming events suggest that many Arctic species had relict distributions during the past inter-glacial periods. Past and present connectivity within Arctic environments has thus played an important role in structuring Arctic species communities, both genetically and ecologically.

There are well-documented negative effects of fragmentation on genetic variation within and between populations, although the consequences of a loss of genetic variability largely depend on the genetic composition of the organisms that become fragmented and locally isolated. In addition, genetic variation is most likely to have consequences on evolutionary time scales, which may not be entirely relevant for the management and utilization of environmental resources. However, recent work has also highlighted the importance of fragmentation for the ecological function of species communities. These studies suggest that the degree of isolation between animal and plant populations could have profound effects on local ecosystem processes and on the supply of ecosystem services. These effects are primarily caused by fragmentation-driven declines in species richness. Species richness influences ecosystem complexity between trophic levels and within communities, with decreased species richness resulting in decreasing ecosystem complexity. In turn, a decrease in ecosystem complexity results in decreased ecosystem stability.

Fragmentation could also influence ecosystem function in other ways, for example, by causing a temporal mismatch between ecologically important events such as plant flowering and pollinator activity. Although not comprehensive, a literature search suggests large biases in our scientific knowledge of the evolutionary and ecological effects of fragmentation in terrestrial and aquatic organisms in the Arctic. Of 43 studies that directly addressed fragmentation in non-marine Arctic organisms, most studies were on terrestrial organisms, and with a geographical bias toward the North American Arctic and Greenland. There was also a taxonomic bias toward mammals, and almost half of the studies were evaluating various forms of genetic variation. Notable was an apparent lack of studies on invertebrates, except for arthropods, a lack of studies on fragmentation effects on pathogens and epidemiology, and a lack of studies on ecological interactions.

A better understanding of the ecological effects of fragmentation may be crucial for our ability to manage and utilize Arctic ecosystems in the face of the challenges posed by climate change. Among knowledge needs on this issue are:

- A quantification of how much more fragmentation will occur under climate change.
- An understanding of the ecological drivers of range shifts: will temperature change or competition from invading species be more important.
- A better understanding of ecological interactions and ecosystem dynamics.
- Information on fragmentation impacts on disease and epidemiology in the biological communities.
- Much more information on and understanding of organism groups other than mammals, arthropods and vascular plants, namely, most of the other species in the Arctic.
- Better knowledge on aquatic environments.
- Cultural, economic and social consequences of fragmentation.

Species communities also become more fragmented with altitude, and species richness declines with altitude. However, local conditions are very important for local community composition; local conditions may cause deviations from expected fragmentation-biodiversity relationships. A better understanding of the consequences of local conditions on the overall effects of fragmentation is needed.

## D12 Panel discussion – Research needs for Arctic biology and ecosystems

To begin the overall discussion on research needs, Anders Mosbech, Aarhus University, Denmark, and researcher on Greenland, stated that in his role as a co-lead on the AMAP Adaptation Actions for a Changing Arctic (AACA) regional group for the Baffin Bay/Davis Strait region, which had a large stakeholder component, he had held workshops in Canada and Greenland for local input. These workshops showed the large number of issues on which local people wanted to receive information. While scientists are good at identifying key questions to improve understanding of ecosystems, this understanding does not really help local stakeholders and the main basis for their living and dealing with conflicts arising from the various competing activities in their area. Research is needed on issues related to conflicts among the various uses of the environment and its resources. The prime importance for a local community is the health and well-being of its residents, more than the biodiversity of the local ecosystems. Nonetheless, it could be very useful to establish cooperation between local residents and research scientists to combine protection of biodiversity with the outcomes of studies (for example, locals collecting down from birds).

In discussing the involvement of researchers with local communities and stakeholders, several points were made and examples provided:

- Before beginning a new research project, scientists, Indigenous People, locals and administrators should meet so that the expectations about the work and its results will be clear and so that the results will be useful to the administrators and will actually be used by them.
- A structure exists in Canada for how to involve local communities. In the First Nation territories, there is a need to apply for a research license from the territorial government and indicate who should be involved. This is very complex and requires a lot of time – many months. There are clear rules of engagement in research. The research plan is reviewed and it requires engagement of locals; it is complicated, but also needed.
- In Sweden, there are no specific rules for cooperation with Sámi. However, there are obligations to inform Sámi society of certain activities; for example, it is not allowed to drive a snowmobile where there is no path. Air space is less regulated, but permission is required for a helicopter to fly over national parks and Sámi areas, as this can be a problem when marking animals and during calving. However, there are no channels for communication with locals when planning work in reindeer herding areas. Sámi can apply for protection of an area during calving, but this is not always respected. Different agencies deal with these issues; for example, county agencies can be contacted if there are activities that are creating disturbances. However, many agencies are located far from the Sámi areas and are not aware of their responsibility on this issue.
- As a resource for consulting with local and Indigenous People, it could be useful to create a regional or community database of relevant people and the types of information that they have that could be accessed by both scientists and Indigenous People and locals.
- There has been much discussion about land-use conflicts. It can help to gain mutual understanding by holding conferences with representatives from tourism, mining and other industries and reindeer herders; this helps in the understanding of the perceptions of the other parties. A broader perspective would be useful. In addition, conflict framing is very effective to understand complex issues; for this, social scientists should be brought into the process.
- Cooperation is essential in all contexts: between scientists and local people; between terrestrial and freshwater studies; and together with Indigenous Peoples. Cooperation is also necessary concerning methods and how the data are stored and used.
- Resources may need to be provided to local people when requesting their assistance.

The need for early inclusion of Indigenous People and the use of Indigenous Knowledge in scientific studies received considerable discussion:

- Indigenous Peoples want to be the owner of their own knowledge. Indigenous People want and need to have their own institutions and to secure their own knowledge. They want to be part of the process and not just give knowledge and lose control of it. Owning knowledge is a factor in being part of the decision-making process.

- Mechanisms need to be developed for full and effective participation in research formulation and implementation and to strengthen the Indigenous Peoples' institutions. Systematic ways are needed to address this cooperation. Indigenous People should be engaged early in the process, while coming to them with already-formulated questions should be avoided.
- A code of conduct may be needed for research cooperation between Indigenous Peoples and scientists. This has been considered by the European Commission.
- There is a need for appropriate infrastructure to facilitate communication among scientists and between scientists and Indigenous Peoples.
- Some cooperation has occurred between the CAFF CBMP Terrestrial Group and Indigenous Peoples; this is intended as true cooperation and not simply receiving their help, but there are few channels for such cooperation. Most relevant people are already very busy.
- Indigenous People may not know about the ways in which scientists could be useful to locals.
- Scientists evaluate their knowledge according to relevant scientific standards; there is a need for Indigenous People to evaluate their own knowledge according to their own standards.

In the overall discussion of issues raised at the workshop, a number of points were made regarding research and other needs in relation to studies of Arctic terrestrial and freshwater ecosystems and Arctic biology:

- If we want to study climate change impacts on ecosystems, it is necessary to study the systems as a whole and not just the parts thereof.
- Research on ecosystem dynamics is important. This includes the need to maintain internal standards for the monitoring and research work and appropriate databases for the results. This will contribute to an ecosystem management framework in the context of biodiversity. Good research combines societal needs, internal scientific standards, and big systems understanding.
- A large amount of data has already been collected on Arctic biota and ecosystems and it is important to really make use of these data.
- There is a need to review the basic foundation for taxonomic work for an entire region. To be able to draw conclusions, the taxonomy should be as good as possible. There is also a very strong need for common standards for methods and taxonomy. Currently it takes a great deal of time to harmonize data sets, given the lack of such standards.
- Much ecological research is local and without knowing conditions in other areas, it is not known how much can be generalized. There are also different biases, so one does not know how much can be concluded locally and what can be concluded on a broader basis.

General points discussed included:

- Research needs should be determined from both society and scientists; societal needs can range from very broad to local.
- In the context of changing landscapes and changing processes, there is a need to determine how these changes affect local people and their way of life.
- Collaboration on large spatial scale assessments of functions and processes requires cooperation with people across the Arctic and with other countries. Harmonization is an important function in large-scale cooperation. In this regard, it was noted that more cooperation between European countries and North America is very much desired, but funding remains a problem for this cooperation. However, new EU research calls are bringing greater possibilities for trans-Atlantic cooperation in research activities.

The lack of coordination between European and Russian scientists on work in the Arctic was considered regrettable, given that roughly half of the Arctic territory is in Russia. Even when there are cooperative arrangements with Russia, it is very difficult for Western scientists to conduct sampling in Russia and to bring samples back for analysis. Furthermore, Russian institutes and the Russian government own their data and researchers are not allowed to share their data. However, some cooperation has occurred on the Yamal Peninsula between Russian scientists and Russian-speaking scientists from Norway; this cooperation can work well scientist-to-scientist when Western scientists can speak Russian. There have also been a number of initiatives to increase cooperation between Russian and UK scientists. Funding is usually not available for Russian scientists to attend conferences on Arctic issues. Germany shares a research station with Russia in the Lena Delta and also financially supports a laboratory in St. Petersburg; it was considered important to retain this cooperation.

## D13 Final remarks and closing of meeting

Nicole Biebow thanked the participants for their proposals. She stated that in two weeks the second Arctic Science Ministerial Meeting would be held in Berlin at which Arctic issues will be discussed including cooperation, data collection and use, and a pan-Arctic observation system. Ministers are now more aware that what happens in the Arctic is influencing their countries, so more funding will be available. She encouraged participants to be active and comment on funding initiatives in the EU. The Co-Chairs stated that this workshop is a good example of cooperation between AMAP and CAFF. They then closed the meeting.

### References

ACIA, 2005. Arctic Climate Impact Assessment. Cambridge University Press.

CAFF, 2013. Arctic Biodiversity Assessment. Status and Trends in Arctic Biodiversity. Conservation of Arctic Flora and Fauna (CAFF), Akureyri, Iceland.

Chapin, F.S., Sommerkorn, M., Robards, M.D. and Hillmer-Pegram, K., 2015. Ecosystem stewardship: A resilience framework for arctic conservation. Global Environmental Change, 34:207-217.

Chamberlain, S.A., Bronstein, J.L. and Rudgers, J.A., 2014. How context dependent are species interactions? Ecology Letters, 17: 881-890.

Culp, J., Goedkoop, W., Lento, J., Christoffersen, K.S., Frenzel, S., Gudbergsson, G., Liljaniemi, P., Sandøy, S., Svoboda, M., Brittain, J., Hammar, J., Jacobsen, D., Jones, B., Juillet, C., Kahlert, M., Kidd, K., Luiker, E., Olafsson, J., Power, M., Rautio, M., Ritcey, A., Striegl, R., Svenning, M., Sweetman, J. and Whitman, M., 2012. The Arctic Freshwater

Biodiversity Monitoring Plan. CAFF Monitoring Series Report No. 7, CAFF International Secretariat, Akureyri, Iceland.

Leonelli, S., Rappert, B. and Davies, G., 2017. Data Shadows: Knowledge, Openness, and Absence. Science, Technology, and Human Values, 42:191-202.

Metcalfe, D.B., Hermans, T.D.G., Ahlstrand, J., Becker, M., Berggren, M., Björk, R.G., Björkman, M.P., Blok, D., Chaudhary, N., Chisholm, C., Classen, A.T., Hasselquist, N.J., Jonsson, M., Kristensen, J.A., Kumordzi, B.B., Lee, H., Mayor, J.R., Prevéy, J., Pantazatou, K., Rousk, J., Sponseller, R.A., Sundqvist, M.K., Tang, J., Uddling, H., Wallin, G., Zhang, W., Ahlström, A., Tenenbaum, D.E. and Abdi, A.M., 2018. Patchy field sampling biases understanding of climate change impacts across the Arctic. Nature Ecology and Evolution, 2:1443-1448.

Soininen, E., E. Fuglei and Å.Ø Pedersen, 2016. Complementary use of density estimates and hunting statistics: Different sides of the same story? European Journal of Wildlife Research, 62:151-160.

Wheeler, H.C., Høye, T.T. and Svenning, J.C., 2018. Wildlife species benefitting from a greener Arctic are most sensitive to shrub cover at leading range edges. Global Change Biology, 24:212-223.

# AMAP / EU-PolarNet International Stakeholder Workshop on Research Needs on Arctic Biology and Terrestrial Ecosystems

## Workshop agenda

*Co-Chairs*: Nicole Biebow (Germany), Joseph Culp (Canada), Willem Goedkoop (Sweden)

**Opening and welcome**
Rolf Rødven, AMAP Executive Secretary

**Context of the workshop: Research needs for EU-PolarNet work**
Nicole Biebow, AWI, Project Manager EU-PolarNet

**Aims and outcome of the workshop**
Janet Pawlak, AMAP Secretariat – Rapporteur

**Summary of research needs on terrestrial ecosystems and climate-related ecosystem changes from the Arctic Biodiversity Congress**
Eefje de Goede, Leiden University, The Netherlands

**Research needs on terrestrial ecosystems and their living resources; impact of climate change**
Eeva Soininen, University of Tromsø, Norway

**Research needs on Arctic biology and biodiversity**
Helen Wheeler, Anglia Ruskin University, UK

**Research challenges in Sápmi in the light of climate change and cumulative effects**
Katarina Inga, Sámi Council

**Summary of research needs on Arctic biology/biodiversity and freshwater ecosystems from the Arctic Biodiversity Congress**
Joseph Culp, Environment and Climate Change Canada

**Research needs on Arctic freshwater systems and freshwater biology; impact of climate change**
Willem Goedkoop, Swedish University of Agricultural Sciences

**Research needs on ecological consequences of a climate driven fragmentation of arctic species communities**
Fredrik Dalerum, University of Oviedo, Spain

**Panel discussion – Research needs for Arctic biology and ecosystems**

**Final remarks and closing of meeting**

## Workshop participants

| Name | Institute |
|---|---|
| Mora Aronsson | Swedish University of Agricultural Sciences, ArtDatabanken, Uppsala, Sweden |
| Nicole Biebow<br>Co-Chair | Alfred Wegener Institute, Bremerhaven, Germany |
| Adrian Braun | Arctic Centre, University of Lapland, Rovaniemi, Finland |
| Joseph Culp*<br>Co-Chair | Environment and Climate Change Canada, WSTD, Wilfrid Laurier University, Geography and Environmental Studies, and Department of Biology, Waterloo, ON Canada |
| Christine Cuyler | Greenland Institute of Natural Resources, Nuuk, Greenland |
| Fredrik Dalerum* | University of Oviedo, Campus de Mieres, Mieres, Spain |
| Laura Forsström | Academy of Finland, Division of Biosciences, Health and Environmental Research, Helsinki, Finland |
| Eefje de Goede* | Leiden University, Leiden, The Netherlands |
| Willem Goedkoop*<br>Co-Chair | Swedish University of Agricultural Sciences, Institutionen för vatten och miljö, Uppsala, Sweden |
| David Grémillet | CEFE/CNRS, Campus du CNRS, Montpellier, France |
| Starri Heidmarsson | Icelandic Institute of Natural History, Akureyri, Iceland |
| Kerstin Holmgren | Swedish University of Agricultural Sciences, Department of Aquatic Resources (SLU Aqua), Institute of Freshwater Research, Drottningholm, Sweden |
| Katarina Inga* | Sámi Council, Kárášjohka/Karasjok, Norway |
| Kimmo Kahilainen | Inland Norway University of Applied Sciences, Elverum, Norway |
| Hanna-Kaisa Lakka | Norwegian University of Science and Technology (NTNU), NTNU University Museum, Norway |
| Jennifer Lento | Canadian Rivers Institute, University of New Brunswick, Fredericton, NB, Canada |
| Ingunn Lindeman | Norwegian Environment Agency, Trondheim, Norway |
| Anders Mosbech | Aarhus University, Denmark |
| Janet Pawlak | AMAP Secretariat, The Fram Centre, Tromsø, Norway |
| Eeva Soininen* | The Arctic University of Norway, Tromsø, Norway |
| Shirow Tatsuzawa | Arctic Research Center/Graduate School of Letters, Hokkaido University, Japan |
| Helen Wheeler* | Anglia Ruskin University, Biology Department, Cambridge Campus, Cambridge, United Kingdom |

* Workshop presenter and panelist.

**AMAP Secretariat**

The Fram Centre,
Box 6606 Langnes,
9296 Tromsø, Norway

T +47 21 08 04 80
F +47 21 08 04 85

www.amap.no

ARCTIC COUNCIL

AMAP
Arctic Monitoring and Assessment Programme

EU-PolarNet
connecting science with society