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Minutes of AMAP/EU-PolarNet Stakeholder Workshop on Research Needs on Arctic Biology and Terrestrial Ecosystems

Date and Venue: 12 October 2018 in Rovaniemi, Finland

Rapporteur: Janet Pawlak, AMAP Secretariat

Participants: See Annex

MEETING AGENDA

Conference Date	**12 October 2018**
Conference Location	**Santa's Hotel Santa Clause, Rovaniemi, Finland**

MEETING TITLE: **AMAP/EU-PolarNet Stakeholder Workshop on Research Needs on Arctic Biology and Terrestrial Ecosystems**

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

Time	
8:30 – 8:50	**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*
8:50 – 10:10	**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*
	Discussion
10:10 – 10:40	Coffee Break
10:40 – 11:50	**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* **Discussion**
11:50 – 12:40	**Panel discussion – Research needs for Arctic biology and ecosystems**
12:40 – 13:00	**Final remarks and closing of meeting**

Executive Summary: Compiled research

Based on the presentations and discussions at the AMAP/EU-PolarNet 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 worldviews 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 EU’s 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 has 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.

1 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 programme. The AMAP/EU-PolarNet Stakeholder Workshop on Research Needs on Arctic Biology and Terrestrial Ecosystems is the fourth and final AMAP-organized international 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.

2 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 the AMAP Secretariat.

3 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 on-line 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).

4 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.

5 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.

6 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 1).

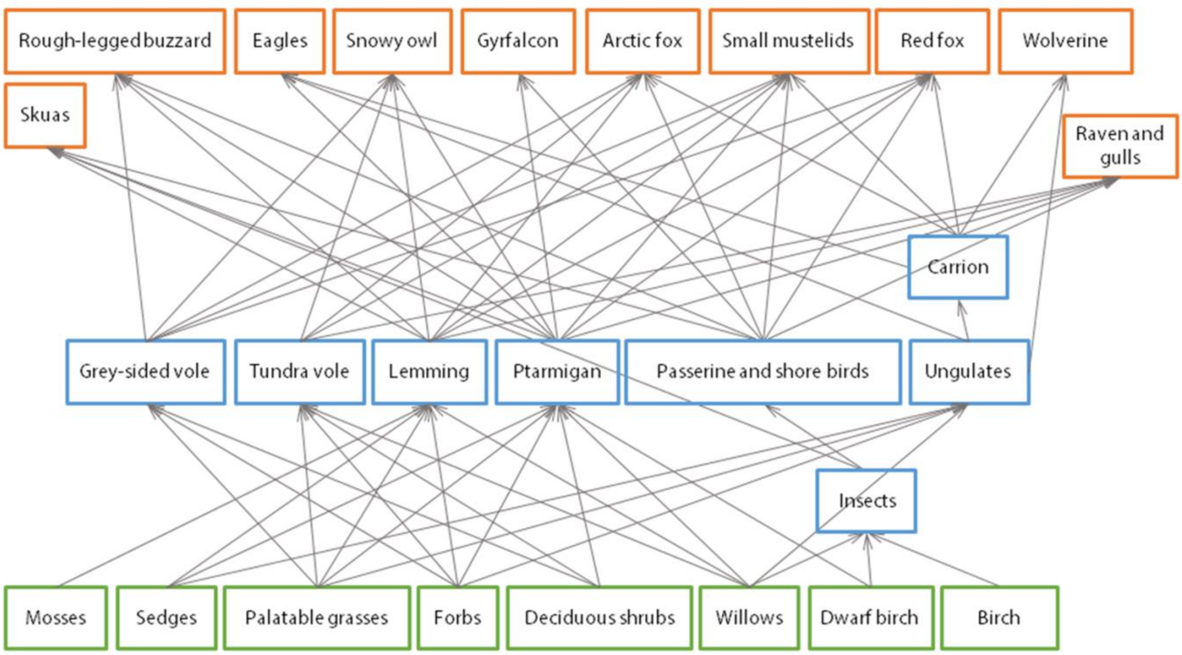

Figure 1. Simplified diagram of a Low Arctic food web. Source: https://www.coat.no/en/Approach

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 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 at https://www.coat.no/en/Ptarmigan/Svalbard). 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 analyis 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.

Eeva Soininen stated that these types of studies 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.

7 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 2).

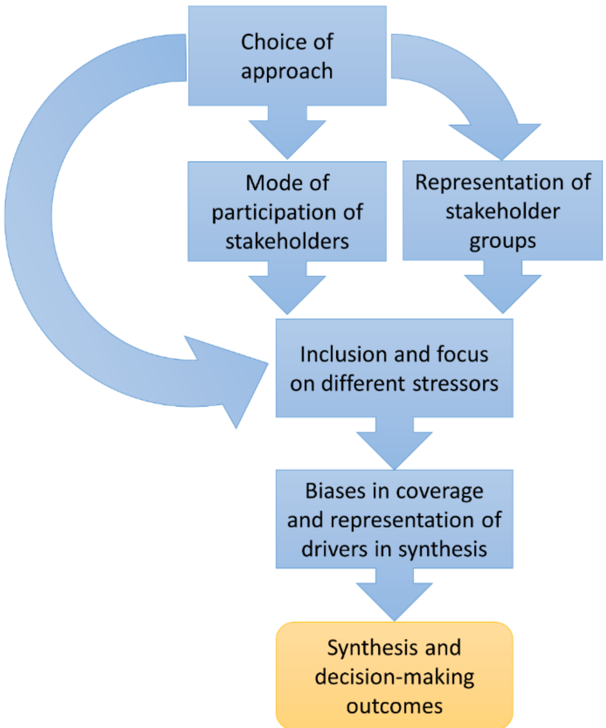

Figure 2. Selected drivers of research biases.

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 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.

8 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 on-going 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.

9 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 3). 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.

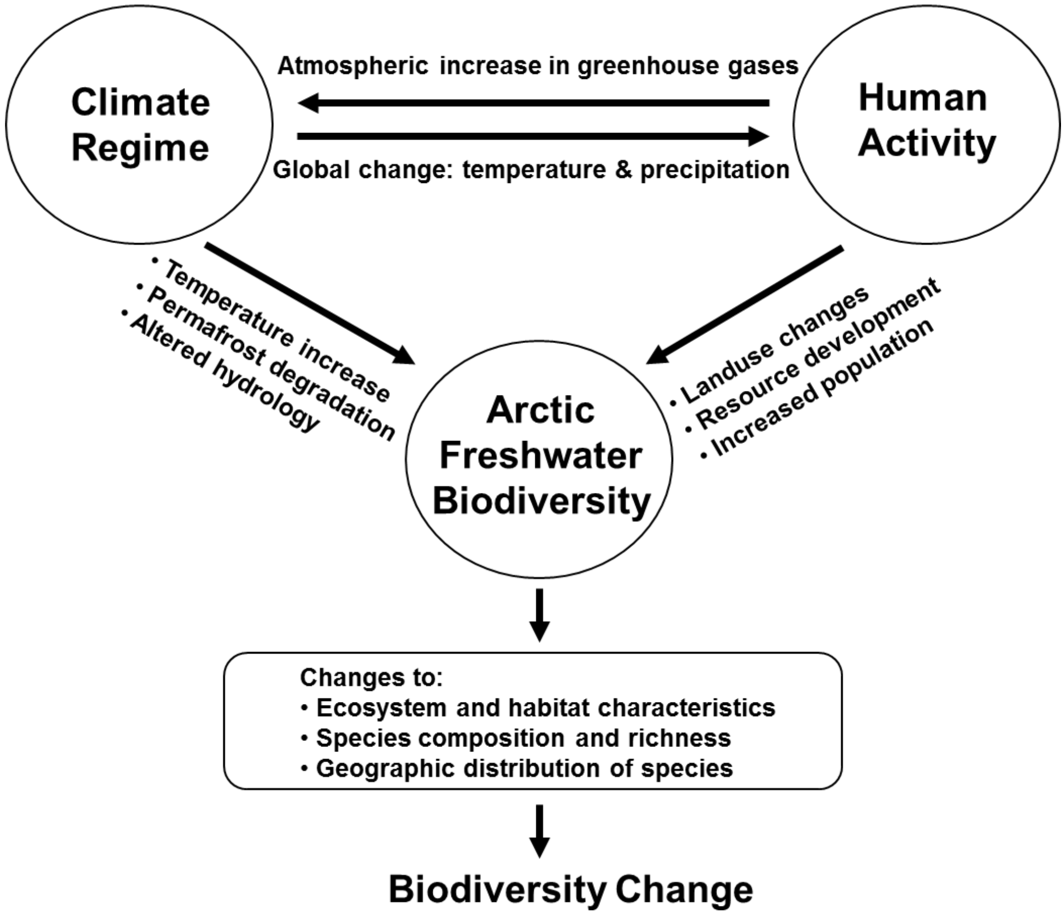

Figure 3. Pressures on Arctic freshwater biodiversity (Culp et al., 2012).

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.

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.

10 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 4).

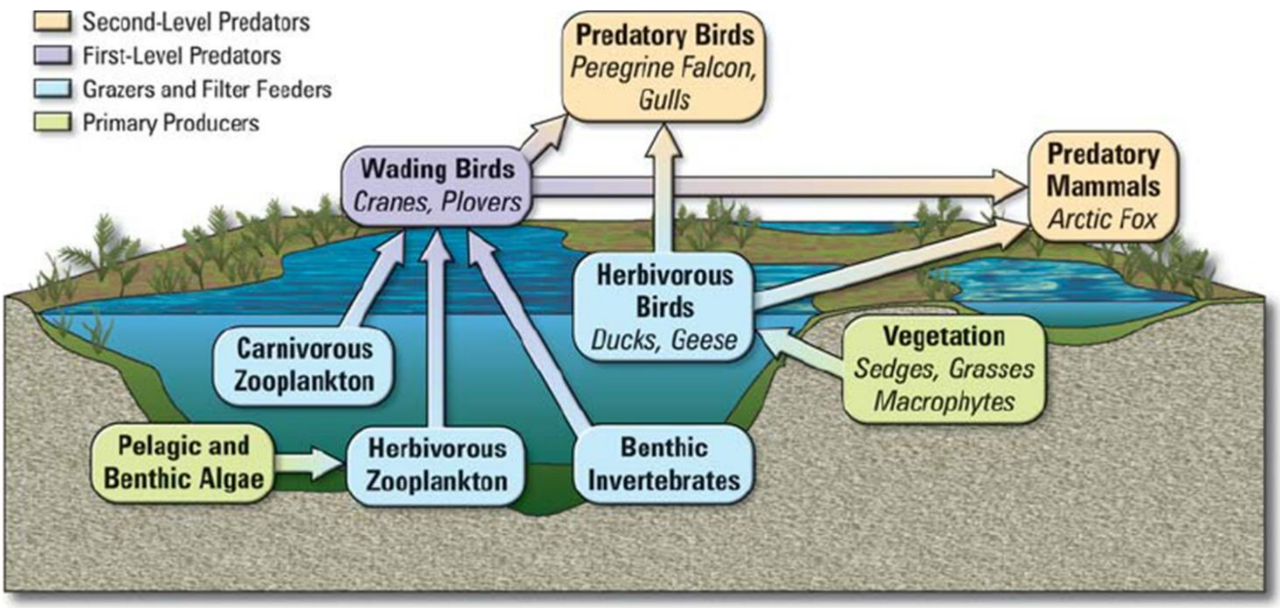

Figure 4. Aquatic and terrestrial food webs are closely linked. (Source: Jim Reist, www.researchgate.net)

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, e.g., 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 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.
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 EU's 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.

11 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.

7 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 together 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.

8 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.

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Annex

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

Rovaniemi, Finland, 12 October 2018

List of Participants

Name	Institute Name and Address	e-mail address
Mora Aronsson	Swedish University of Agricultural Sciences, ArtDatabanken, Uppsala, Sweden	Mora.Aronsson@slu.se
Nicole Biebow	Alfred Wegener Institute, Bremerhaven, Germany	nicole.biebow@awi.de
Adrian Braun	Arctic Centre, University of Lapland, Rovaniemi, Finland	adrian.braun@ulapland.fi
Joseph Culp	Environment and Climate Change Canada, WSTD, Wilfrid Laurier University, Geography and Environmental Studies, and Department of Biology, Waterloo, ON Canada	joseph.culp@canada.ca jculp@wlu.ca
Christine Cuyler	Greenland Institute of Natural Resources, Nuuk, Greenland	Chris.cuyler@natur.gl
Fredrik Dalerum	University of Oviedo, Campus de Mieres, Mieres, Spain	dalerumjohan@uniovi.es
Laura Forsström	Academy of Finland, Division of Biosciences, Health and Environmental Research, Helsinki, Finland	laura.forsstrom@aka.fi
Eefje de Goede	Leiden University, Leiden, The Netherlands	e.m.de.goede@cml.leidenuniv.nl
Willem Goedkoop	Swedish University of Agricultural Sciences, Institutionen för vatten och miljö, Uppsala, Sweden	Willem.Goedkoop@slu.se
David Grémillet	CEFE/CNRS, Campus du CNRS, Montpellier, France	David.GREMILLET@cefe.cnrs.fr
Starri Heidmarsson	Icelandic Institute of Natural History, Akureyri, Iceland	starri@ni.is
Kerstin Holmgren	Swedish University of Agricultural Sciences, Department of Aquatic Resources (SLU Aqua), Institute of Freshwater Research, Drottningholm, Sweden	kerstin.holmgren@slu.se
Katarina Inga	Sámi Council, Kárášjohka/Karasjok, Norway	Katarina.inga@biegga.com
Kimmo Kahilainen	Inland Norway University of Applied Sciences, Elverum, Norway	Kimmo.kahilainen@inn.no
Hanna-Kaisa Lakka	Norwegian University of Science and Technology (NTNU), NTNU University Museum, Norway	Hanna-kaisa.lakka@helsinki.fi Hanna-kaisa.lakka@ntnu.no
Jennifer Lento	Canadian Rivers Institute, University of New Brunswick, Fredericton, NB, Canada	jlento@gmail.com
Ingunn Lindeman	Norwegian Environment Agency, Trondheim, Norway	ingunn.lindeman@miljodir.no
Anders Mosbech	Aarhus University, Denmark	amo@bios.au.dk
Janet Pawlak	AMAP Secretariat, The Fram Centre, Tromsø, Norway	jpawlak@dahm.dk
Eeva Soininen	The Arctic University of Norway, Tromsø, Norway	eeva.soininen@uit.no
Shirow Tatsuzawa	Arctic Research Center/Graduate School of Letters, Hokkaido University, Japan	serow@eis.hokudai.ac.jp
Helen Wheeler	Anglia Ruskin University, Biology Department, Cambridge Campus, Cambridge, United Kingdom	helen.wheeler@anglia.ac.uk