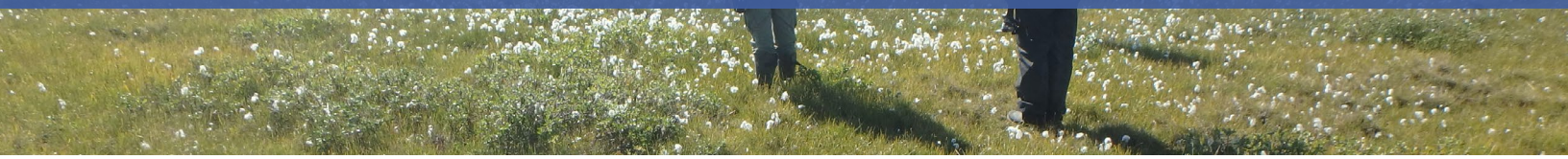
THE CANADIAN ARCTIC MONITORING AND PREDICTION SYSTEM (CAMPS): A proposal for a coordinated knowledge system to understand and anticipate change in Canada's northern ecosystems



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Abstract

It is now well documented that Canada's North is changing and these changes are having and will continue to have important impacts on communities, on the mandates of government agencies, and on understanding and mitigating impacts of industrial development. Due to systemic issues with research delivery, our present state of knowledge is limited both spatially and temporally, and is insufficient to provide the depth and breadth of knowledge required to monitor, understand, and predict change; reduce the potential for ecological surprise; and inform proactive adaptive management decisions. The Canadian Arctic Monitoring and Prediction System (CAMPS) is a proposal to initiate a national dialogue among all northern actors towards the development of a strategic northern knowledge system that would aim to coordinate ongoing science initiatives to optimize present investments, propose new strategic science investments, and mobilize the intellectual capital of Indigenous knowledge (IK) that is present in northern communities. Key elements of CAMPS include (1) long-term, strategic investments to sustain northern research infrastructure and support coordinated, multiscale, long-term, hypothesis-based monitoring experiments for northern terrestrial and freshwater ecosystems; (2) long-term investments in northern communities to build local capacity and engage IK so that science-community partnerships can be established and communities can act as a coordinated network of ecosystem observatories; and (3) coordination of these initiatives with ongoing monitoring by government agencies, universities, land claim bodies, communities, and industry to develop regional to national assessments of ecological change in Arctic and Subarctic ecosystems, and make predictions on near- and long-term change. It is proposed that an effective path forward would be to plan and develop a regional-scale implementation of CAMPS as a proof of concept to demonstrate the feasibility and usefulness of the proposed approach.

Résumé

Il est maintenant bien documenté que le Nord canadien est en train de changer et que ces changements ont et continueront d'avoir des répercussions importantes sur les collectivités, sur les mandats des organismes gouvernementaux et sur la compréhension et l'atténuation des répercussions du développement industriel. En raison de problèmes systémiques liés à la prestation de la recherche, notre état actuel des connaissances est limité sur les plans spatial et temporel, et il est insuffisant pour fournir la profondeur et l'ampleur des connaissances nécessaires pour surveiller, comprendre et prévoir les changements, réduire le risque de surprise écologique et éclairer les décisions proactives de gestion adaptative. Le système

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canadien de surveillance et de prévisions des conditions météorologiques dans l'Arctique (Canadian Arctic Monitoring and Prediction System ou CAMPS) est une proposition visant à amorcer un dialogue national entre tous les intervenants du Nord en vue de l'élaboration d'un système stratégique de connaissances pour le Nord qui viserait à coordonner les initiatives scientifiques en cours afin d'optimiser les investissements actuels, de proposer de nouveaux investissements scientifiques stratégiques et de mobiliser le capital intellectuel du savoir autochtone (SA) présent dans les collectivités du Nord. Les éléments clés du CAMPS comprennent (1) des investissements stratégiques à long terme visant à maintenir l'infrastructure de recherche dans le Nord et à soutenir des expériences de surveillance fondées sur les hypothèses coordonnées, multiéchelles et à long terme pour les écosystèmes terrestres et d'eau douce du Nord; (2) des investissements à long terme dans les collectivités du Nord en vue d'accroître la capacité locale et de faire appel à la SA afin que des partenariats entre le milieu scientifique et les collectivités puissent être établis et que les collectivités puissent servir de réseau d'observatoires pour les écosystèmes côtiers et marins du Nord; (3) la coordination de ces initiatives avec la surveillance continue par des organismes gouvernementaux, des universités, des organismes de revendications territoriales, des collectivités et l'industrie afin d'élaborer des évaluations régionales à nationales des changements écologiques dans les écosystèmes arctiques et subarctiques, et faire des prédictions sur les changements à court et à long terme. On propose une marche à suivre efficace qui consisterait à planifier et à élaborer une mise en œuvre régionale du CAMPS comme preuve de concept afin de démontrer la faisabilité et l'utilité de l'approche proposée.

Introduction: Knowledge needs in a changing Arctic

It is well acknowledged that climate is warming much more rapidly in the Arctic and Subarctic than in southern latitudes (IPCC 2014; Serreze et al. 2009) — warming that is driving important changes in the abiotic-biotic interactions that in large part determine the abundance and health of many northern species (Settele et al. 2014). In Arctic coastal-marine systems, a decreased sea-ice season and warmer seawater are directly impacting sea-ice-dependent biota (Eamer et al. 2013; AMAP 2017), while sea-level rise and increased rates of coastal erosion (Forbes 2011; Gunther et al. 2015; Lantuit et al. 2015) are impacting vulnerable coastal wetlands that provide critical staging and nesting habitats for many migratory shorebird and waterfowl species (Provencher et al. 2018; Jorgensen et al. 2018). The degradation of permafrost on exposed lakeshores and riverbanks, and the deepening of soil-active layers, are impacting biota in freshwater systems (Balzer et al. 2014; Sniderhan and Balzer 2016) and changing the quality and quantity of river discharge to coastal marine ecosystems — a key determinant of physical processes that directly and indirectly affect coastal marine species (Frey et al. 2009; Carmack et al. 2016; Alkire et al. 2017). In terrestrial ecosystems, warming air and soil temperatures, degrading permafrost, and reduced snow season are causing infilling and changes in the relative dominance of shrubs, with unknown habitat effects (Myers-Smith et al. 2011; Tape et al. 2006, 2012). In some areas, historical lemming cycles are reduced or have crashed, with potentially cascading effects on the many species that prey on them (Schmidt et al. 2014). Northern caribou populations are at historic lows (Gunn et al. 2010; Parlee et al. 2018; CARMA 2018) and disease-driven muskoxen diebacks are occurring in the western Arctic — trends that at this time are largely unexplained (Kutz et al. 2015). Other factors, such as ocean acidification (Steinacher et al. 2009; Yamamoto-Kawai 2009), increased contaminants (Schuster et al. 2018), invasion by southern species (Lawler et al. 2009), and increased tourism, military activity, and industrial development all have the potential to significantly impact northern biota.

What is clear at this time is that environmental change is ongoing, is accelerating, and is happening across all ecosystems of the Canadian North at different rates and with differing effects, depending on the regional setting. Taken together, these ongoing changes interact in complex ways across spatial and temporal scales to create high levels of uncertainty for government and regional agencies with biodiversity conservation mandates, communities dependent on wild harvest (i.e., country food) and healthy ecosystems, and industrial proponents and operators charged with minimizing and mitigating potential impacts of ongoing and proposed developments.

The need for a national-scale approach

As a result of the broad variability in geographic scope in Canada's northern ecosystems and the overall complexity of predicted changes and their interactions, it is proposed here that a national-scale strategic approach is needed to develop a deep understanding of how and why these changes are occurring, in order to anticipate change and help develop proactive adaptation strategies for the North. At the present time in northern Canada, monitoring and research that could contribute effectively to our understanding of these myriad changes is largely fragmented and uncoordinated. For example, many government departments conduct excellent research and monitoring programs that are implemented to fulfill their stated mandates, but these programs are poorly linked to related work by academic organizations, industry, or communities. Canada is fortunate to have a culture of active world-class northern scientists, and although some academic researchers have managed to maintain research sites that sustain long-term monitoring and research programs, they are by necessity limited temporally because of short-term funding arrangements and spatially because of the limited geographic scope of their research areas. Arctic communities hold a wealth of Indigenous knowledge (IK), and although some community-based monitoring is occurring across the Arctic and Subarctic, programs generally lack long-term sustainability and regional linkages, and in many cases, IK is not effectively mobilized.

These systemic problems in our northern research and monitoring structure mean that we are not in a position to understand or predict important changes at a scale relevant to the potential impact of the changes. For example, changes in terrestrial ecosystems, such as the relative dominance of shrubs, input of soil carbon to the atmosphere, arrival of new species, and length of the growing season are well documented locally. A critical question is, how are these local changes playing out on regional and national scales in terms of overall contributions of carbon to the atmosphere, changes in land feedbacks to climate, progress of northward-migrating species, and changes in habitat for wide-ranging species such as caribou? To provide answers to this multi-faceted question and others, a long-term, multi-scale experimental monitoring approach that coordinates northern science and IK resources is needed. This approach would implement these long-term, monitoring experiments across a sustained observatory network, which would capture northern ecological variability in terrestrial, freshwater, and coastal-marine ecosystems. This approach would also build on and connect present programs and attract new investments, which would support a strategic national approach to monitoring and research in Canada's North. In addition to the required funding, a key challenge will be to coordinate the wide range of actors that can contribute to such a network, including federal governments, territorial governments, land claim institutions, communities, Indigenous organizations, industry, academics, and NGOs.

CAMPS: A proposal for a Northern knowledge system

The Canadian Arctic Monitoring and Prediction System (CAMPS) is a proposal to measure, understand, and predict biodiversity change, associated abiotic drivers, and ecological processes in a coordinated way, at a range of scales across the Arctic and Subarctic terrestrial, freshwater, and coastal-marine ecosystems of northern Canada. CAMPS can initiate a national dialogue among all northern actors, which can lead towards the development of a strategic northern knowledge system that will coordinate ongoing science and community initiatives. This coordination will optimize present investments, propose new strategic science investments as needed, and more effectively mobilize the intellectual capital and IK present in northern communities. Key elements of CAMPS include (1) long-term investments to sustain northern research infrastructure, utilizing and supporting the present array of research sites to establish a connected northern observatory network that would establish and maintain coordinated, long-term monitoring experiments; (2) long-term experiments established in the observatory network, which would be designed to quantify relationships among abiotic drivers, ecosystem processes, and targeted biotic outcomes (e.g., species of interest, habitat changes, changes in land/sea to atmosphere feedbacks), so that local-scale, process-based models could be developed and extrapolated to regional and national scales using remote-sensing tools; (3) long-term investments in northern communities to build local capacity and engage IK, establishing science-community partnerships that would implement a network of northern community observatories, especially in coastal-marine ecosystems; and (4) coordination of these new initiatives, with ongoing monitoring by government agencies, universities, land claim bodies, communities, and industry, in order to develop regional and national assessments of ecological change and the state of Arctic and Subarctic ecosystems, and make predictions on short- and long-term change.

CAMPS, as proposed, has three levels (Fig. 1). The

foundation of the system is the northern observatory network, with a flagship monitoring site at the Canadian High Arctic Research Station (CHARS) as the hub. The observatory network would be initiated with existing northern research sites (e.g., research stations organized under the Centre d'études nordiques, the Canadian Network of Northern Research Operators, and the Changing Cold Regions Network) would monitor terrestrial and freshwater systems, and would be piloted in selected coastal communities, with supporting coastal boats (e.g., small craft from communities, small ships from the Arctic Research Foundation) and larger ships (e.g., Canadian Coast Guard icebreakers) for monitoring coastal marine ecosystems. Based on the input and direction of relevant science teams and IK experts, each site would implement and maintain coordinated, long-term monitoring experiments that link abiotic drivers and ecological processes to biodiversity outcomes in terrestrial, freshwater, and coastal-marine ecosystems. To develop consensus on the design and analysis of the long-term experiments, it is proposed that we convene subject-area experts to develop experimental approaches that reflect the latest best practices in their fields (e.g., for terrestrial monitoring, disciplines would include soil processes such as microbiology, soil physical processes, permafrost and nutrient cycling, vegetation change at a range of scales as well as faunal change in small mammals, shorebirds/songbirds, and arthropods).

The intermediate level of the system would work to access and incorporate surveillance monitoring data from the wide variety of mandate-based monitoring programs conducted by various northern federal and territorial government agencies, land claim co-management boards, industry, academic organizations, and community-based monitoring programs. With coordination, results from these programs could be used to calibrate and validate regional-scale, remote-sensing-based models that reach out from long-term monitoring experiments conducted through the observatory network.

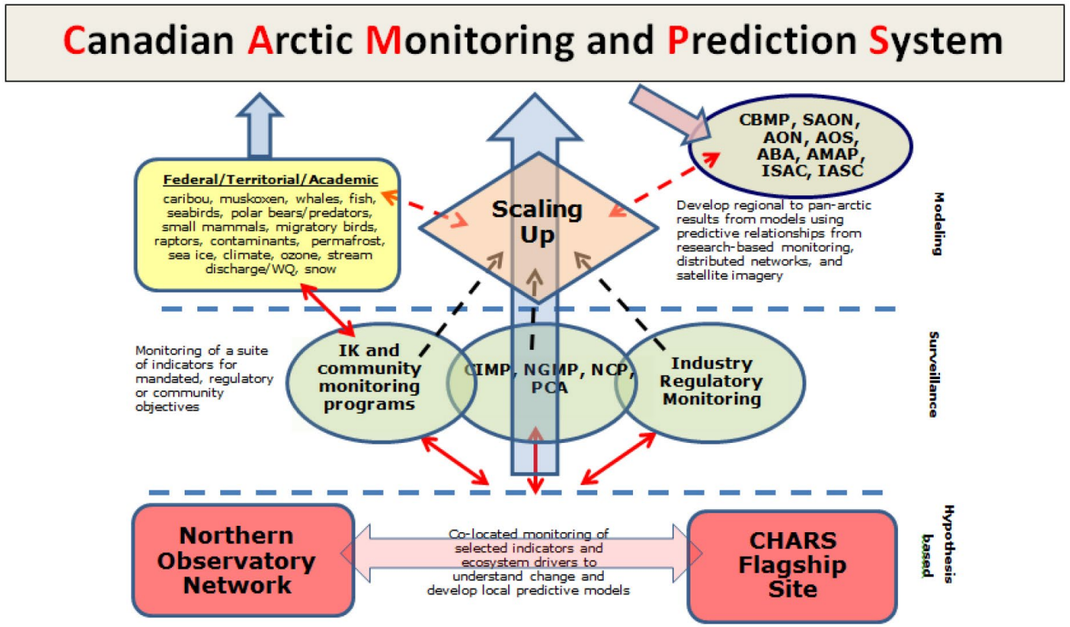

Figure 1: Schematic of the proposed Canadian Arctic Monitoring and Prediction Network (CAMPS) — see text for discussion. IK = Indigenous Knowledge; CIMP = Cumulative Impact Monitoring Program; NGMP = Nunavut General Mentoring Program; NCP = Northern Contaminants Program; PCA = Parks Canada Agency; CBMP = Circumpolar Biodiversity Monitoring Program; SAON = Sustained Arctic Observing Network; AON = Arctic Observing Network; AOS = Arctic Observing Summit; ABA = Arctic Biodiversity Assessment; ISAC = International Study of Arctic Change; IASC = International Science Committee.

The third and final level of CAMPS would use observatory data and regional and national models from the observatory network, species-specific or targeted monitoring data from government departments and academia, and other data from the intermediate level of mandate-based monitoring programs to develop remote-sensing-based models that would extrapolate local results to regional and national scales in order to make predictions of change using appropriate monitoring measures (e.g., changes in vegetation composition, structure, and productivity caused by climate-driven change in soil and site drivers; changes to freshwater systems brought about by accelerating permafrost degradation and changes in snow regime; and changes in sea-ice biota resulting from sea-ice changes and warming water).

Community considerations

The success of CAMPS will rely heavily on the meaningful engagement and involvement of northern community members, community and regional governing bodies, and associated Indigenous organizations. An important aspect of CAMPS is to build on and support the Indigenous knowledge and experience inherent in northern communities — knowledge and experience gained from centuries of observing and accessing natural resources. The proposed approach establishes community-science partnerships and develops a network of northern communities to work as equal partners with researchers in the design, implementation, and dissemination of research while having access to information gathered about communities and control over how the information is used and disseminated (ITK 2016). Investments in community training, employment, and infrastructure, and meaningful input into the design of the long-term monitoring to be implemented, would contribute to self-determination and sustainable economies in participating communities. Community-based research and monitoring is central to the success of CAMPS and includes two key activities: (1) activities initiated and implemented by the communities to address key community needs (supported by science as requested) and (2) activities that are part of regionally coordinated, science-based activities, where community members would be employed and receive training, science support, and equipment to conduct the monitoring. It is very important that information gathered using community-based monitoring approaches be collected through the use of standard protocols and designs so as to link effectively to regional CAMPS activities.

Discussion

Key to this proposal is the engagement and coordination of a range of northern actors on a scale that has not been achieved to date, and it is important not to underestimate the challenge in achieving such involvement. On the other hand, coordination across mandates, agencies, and organizations has been seen as a worthy goal by all actors for many years. Successful partnerships will be successful if they benefit all parties in relation to the investment each party makes in the proposed northern knowledge system. The Canadian North is vast, with poor access and large knowledge gaps, and all northern actors are limited in terms of the funding and expertise needed to understand the complex, interacting, and accelerating ecological changes that are happening. Although ambitious, such a coalition is absolutely necessary to achieve the goals of CAMPS.

In addition to meaningful community engagement, another key to the success of this proposal is to work towards securing long-term funding for the network of research sites that would implement the coordinated experiments. This funding would make a significant contribution to "keeping the lights on" at research sites and providing training and employment support for northern technical staff who would maintain monitoring experiments over the long term. Such an investment would have the side benefit of helping to secure these sites for research science of all kinds, the results of which are needed to support the development and evolution of the coordinated, long-term monitoring experiments.

It is anticipated that implementation of CAMPS would occur regionally, to take advantage of existing regional partnership and activities, but a standardized approach to long-term experiments and the scaling up of models would permit national synopses of regional activities. If implemented, CAMPS would provide useful and timely information at a range of scales on ongoing and predicted changes in northern ecosystems, which would support proactive adaptation approaches for northern communities, industries, and governments. Investments in CAMPS would support academic research at a strategic network of northern research sites, provide capacity building to northern communities, support resilience and self-determination in these communities, and optimize present investments in northern science.

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