Community-Based Monitoring and Indigenous Knowledge in a Changing Arctic:

A Review for the Sustaining Arctic Observing Networks

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Executive Summary

This review of community-based monitoring (CBM) in a changing Arctic is based on a multi-year initiative launched in 2012 as a task under the "Sustaining Arctic Observing Networks" (SAON), a network of Arctic observing networks. The goal of the task was to better understand the current state of CBM in the Arctic, with a particular interest in monitoring and observing based on Indigenous Knowledge (IK), and to make recommendations to SAON and the Arctic observing community more broadly about how to support engagement and development of CBM.

The task began with the creation of a searchable, online inventory of CBM and IK programs, projects, and initiatives: the Atlas of Community-Based Monitoring and Indigenous Knowledge in a Changing Arctic (www.arcticcbm.org). The Exchange for Local Observations and Knowledge of the Arctic (ELOKA) developed this web-based atlas infrastructure on the Nunaliit Atlas Development Framework (http://nunaliit.org). The Atlas geolocates these various initiatives, visualizes the networks of communities that are involved, and shares metadata provided or verified by program staff.

Identification and recruitment of CBM and IK initiatives to join the Atlas involved a number of strategies. We intentionally did not pre-define CBM, but adopted an inclusive approach that encompassed programs with different levels of community involvement as well as IK projects with relevance to long-term observing. We conducted initial outreach to a

The Sami people, also spelled Sámi or Saami, are the indigenous Finno-Ugric people inhabiting the Arctic area of Sápmi. This is a small siida, a reindeer foraging area. Credit: Harvey Barrison

number of Indigenous organizations and government and academic researchers engaged in monitoring and observing activities. At the pan-Arctic level, Arctic Council Permanent Participants (PPs), and the SAON and Conservation of Arctic Flora and Fauna (CAFF) boards were briefed and asked to refer programs. Once programs were identified, program staff were asked to fill out a questionnaire to provide metadata about their initiative. In some cases, phone interviews were conducted and program staff were asked to approve a pre-filled questionnaire. Completed questionnaires were reviewed and entered into the Atlas by a trained member of the research team to ensure consistency of entries. As of September 2015, the Atlas included 81 program entries.[1]

The second component of the SAON task was to analyze these entries alongside information gathered from participation of several of this review's authors in a series of workshops on CBM and IK held in 2013 and 2014[2]; this analysis informed the development of the review. The goal of the review is to provide a snapshot of the methods, approaches, and practices of CBM and IK initiatives, and to present recommendations for next steps in supporting the continued development of CBM as an important approach to Arctic observing. The intended audience of this review includes CBM and IK program practitioners and interested community members, scientists and researchers interested in different approaches to Arctic observing, individuals engaged in developing approaches and networks for data sharing and coordination, and municipal, state/territorial, and national government agencies interested in community-based approaches to monitoring. The review contains the following sections: General overview of programs in the Atlas; Specific issue areas; Good practices; and Next Steps.

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1. We continue to recruit and add new programs to the Atlas; if your program would like to be included, please contact: arcticcbm@inuitcircumpolar.com.
2. Workshops included: "From Promise to Practice: Community-Based Monitoring in the Arctic" organized by Oceans North, held in Cambridge Bay, Nunavut, 19-21 Nov. 2013; "Symposium on the Use of Indigenous and Local Knowledge to Monitor and Manage Natural Resources", organized by Greenland Department of Fisheries, Hunting and Agriculture, NORDECO and ELOKA, held in Copenhagen, Denmark, 2-3 Dec. 2013; "Global Change, Indigenous Community-Based Observing Systems, and Co-Production of Knowledge for the Circumpolar North", organized by UNESCO, CNRS/MNHN and the International Centre for Reindeer Husbandry, held in Kautokeino, Norway, 25-27 Mar. 2014.

Opposite page: Icebergs drift in a mountain-ringed Greenland fjord. Ice covers over three-quarters of Greenland, the world's largest island. The mainland is mainly permafrost, a thick subsurface layer of soil that remains frozen yearlong. With only the coasts free of ice, a sparse population manages to thrive. Credit: Frans Lanting

Using traditional fishing techniques, a fisherman pulls in a vendace fish trap, Lake Puruvesi, North Karelia, Finland. Credit: Chris McNeave

General overview of programs in the Atlas

We analyzed metadata from the 81 programs across the circumpolar region that were in the Atlas as of September 2015 to provide a snapshot of the state of CBM and IK programs relevant to observing and monitoring.[3] The analysis includes a discussion of the program start date and current status (active/inactive), program objectives, issues of concern, the role of IK, involvement of community members, data collection methods and approaches, intended scale of information use, and data management. The main findings of the analysis are:

- ❄ Thirty-four programs were based in North America, 37 in Europe, and 9 in Russia, with one additional program co-located in Europe and Russia.
- ❄ More than half of the programs had multiple community sites within a single country, and some had multiple locations in more than one country.
- ❄ Nearly three-quarters were started within the last decade (2005-2014), the remaining between 1917 and 2004.
- ❄ Nearly three-quarters of programs are currently active (either "ongoing" or "in progress"), with around one quarter complete and a few "on hold" due to lack of funding.
- ❄ Programs monitored a wide variety of attributes that we clustered into five broad areas of focus: management of land and resources; wildlife; vegetation; abiotic phenomena such as ice, snow, and water; and socio-cultural attributes such as language transmission, health, and wellness.
- ❄ Sixty-nine percent engaged IK in some capacity, with methods that included interviews, focus groups, and participatory mapping.
- ❄ Twenty-eight percent of programs reported involving both IK and science for supporting decision-making based on multiple evidence bases.
- ❄ Forty-seven percent involved community members in design, data collection, and analysis, while the remaining programs engaged community members in one or two of these phases, or in project design. Thirty percent involved community members in data collection only.
- ❄ Programs used a variety of data collection methods, including collection of physical or biological observations/samples/measurements (47 percent) as well as qualitative approaches such as interviews, surveys, workshops, and literature review and documentary analysis (34 percent). Some programs combined physical observations and sample collection with qualitative methods (19 percent).
- ❄ Fifty-four percent of programs reported making their data accessible to the public, but in most cases this was by request only; thirty-four percent made a data synthesis available.

Specific issue areas

Many of the programs in the Atlas were initiated based on a perceived need for data and observations that could support decision-making in the context of socio-environmental change. In this section, we highlight several issue areas that illustrate some of the underlying matters of concern to communities that have led to the creation of CBM initiatives, including:

- ❄ Monitoring the impacts of development and extractive industry, including land use change and hydro-electric development
- ❄ Contaminants, including from industry and military installations located near communities, as well as long-range transport from outside the Arctic
- ❄ Species population monitoring, biodiversity, and food security

Under each of these issue areas, we share examples of programs from the Atlas that are using CBM and IK documentation to help equip communities with information they need to respond.

Good practices

We identify and highlight eight good practices, drawn from discussions held at the three workshops as well as our analysis of practices reported by programs in the Atlas. Because we believe the field of CBM would benefit from additional processes to identify best practices that should involve community members, IK holders, CBM practitioners, and scientists, we choose to call these "good practices" rather than "best practices." Good practices discussed in the review include:

1. *Build capacity:* Communities have very different levels of capacity to initiate, participate in, and benefit from monitoring initiatives. CBM initiatives benefit from strong local

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3. With a few exceptions, we use the word "programs" rather than "projects" in this review to reflect the idea that monitoring initiatives are intended to collect data and information over a long period (monitoring). However, we did not adopt a strict categorization in our methodology (see below); the Atlas includes a number of shorter-term research projects whose results/data can be useful to informing longer-term monitoring initiatives.

(Left & Right) A reindeer stands apart from the herd of Nenets reindeer in Siberian Russia. Credit: Evgeniy Volkov; (Center) A small Sami village in Saltdal, Nordland, Norway. The door is purposefully built high and on a slant to allow for heavy snowfall. Credit: Maria Victoria Rodriguez

institutional capacity and can also contribute to capacity building and knowledge transfer by providing training and support for Indigenous and local institutions.

2. *Co-produce observations and utilize IK:* Many CBM programs draw on both IK and conventional scientific approaches and technologies. IK can contribute in a variety of ways, such as building a conceptual framework, contributing and analyzing observations, and helping identify monitoring priorities as well as the best sites for monitoring stations. Co-production approaches draw on IK and scientific methods to develop novel questions and document and interpret observations based on two ways of knowing.

3. *Recognize and engage diversity within communities:* Although Arctic communities are internally diverse, there is a tendency for CBM programs to focus more on involvement of men's knowledge and land-based activities. Only two projects in the Atlas, for example, focused specifically on women's knowledge and activities. Additionally, greater involvement of youth would create opportunities for skills building in environmental research and management and for transmission of IK between generations.

4. *Adapt technologies to respond to community information needs and infrastructure inequities:* Unequal access to information and communications technologies (ICTs) remains a critical challenge across the circumpolar region. ICTs can be used to collect, store, process, and share environmental observations and data, including IK and traditional land use practices. Adapting technologies for CBM can be expensive, however, and requires a thoughtful approach to ensure that investments contribute to observing capacity over the long term.

5. *Scale observations and support network building:* One of the characteristics of CBM is that it is often initiated for community monitoring needs and purposes. Because responding to Arctic change requires decision-making across scales, there is a need for monitoring data that can inform regional, national, and pan-Arctic decision-making. The formation of networks is a critical part of disseminating and/or scaling CBM related information. Networks serve as conduits for the flow of knowledge and information both within communities as well as between them, and between community institutions and actors and institutions outside the community. Developing CBM networks will require consideration of information and advocacy needs at different scales and across different regions.

6. *Use CBM to inform decision-making and natural resource management:* Projects in the Atlas describe a variety of uses for the monitoring information they provide, including informing individual, household, community, and government decision processes. The emphasis can be on providing information for one scale of decision-making or multiple scales simultaneously. Communities may not always be aware of all relevant decision-making venues for sharing CBM-generated data and information. Assessing this and considering the political implications of different scales of action would strengthen community capacity for policy engagement in the long term.

7. *Develop data management protocols for CBM and IK:* There is no single standard data management protocol that applies to all circumpolar regions and communities, and it is important for CBM programs to follow and support local and regional guidelines for research involving IK and community-based observing. As CBM projects develop systems of collecting, storing, and sharing data, and as interest in CBM grows in the larger Arctic observing community, new protocols are needed that can facilitate transfer and sharing of diverse types of observations. These protocols should facilitate sharing across platforms (interoperability) and between knowledge systems so that they relay IK based observations in the ways that IK holders intend.

8. *Sustain CBM Programs:* Sustainability challenges for CBM programs include a lack of long-term funding opportunities, as well as challenges posed by staff turnover, communication difficulties, and failures of programs to adequately report back findings or link data to community goals. There is general but not universal agreement that financial compensation of community observers is an important component of sustaining community support. Programs can increase the likelihood that they can be sustained over time by building on locally available human capacity and financial resources. A significant factor for sustaining programs is ensuring their relevance to community priorities and concerns.

Next Steps

As an observing network, SAON can support the further development of CBM. We see a particular role for SAON in the following areas:

1. *Supporting identification of best practices and standards for community involvement.* This review represents an initial step in examining different approaches to CBM from a circumpolar perspective. The scope of this process was limited, however, and many of the conclusions and findings are based on the interpretation of a relatively small group of authors. There is a need for a broadly inclusive, bottom-up process to identify best practices for community-based monitoring, including standards for community leadership and involvement. Because of differences in approach and varying governance arrangements in different parts of the Arctic, this may be more effective as a series of regional efforts accompanied by strong communication between regions. SAON can play a role in supporting these efforts by recognizing their importance to advancing CBM and by disseminating results within the international Arctic observing community.

2. *Promoting data and methods standardization.* Although support for CBM should enable diverse approaches to data collection depending on the specific goals of the community, SAON can play a role in promoting greater standardization and coordination of methods for data collection that is culturally appropriate and supports the knowledge system/s from which the data are derived. This may be particularly relevant for those programs that wish to make data available for assessment processes and decision-making at regional and pan-Arctic levels. While data standardization is an important overall goal to facilitate data sharing and use, care must be taken to allow for overall flexibility that can support involvement of diverse methodologies and knowledge sources and nurture the knowledge systems from which the data is derived.

3. *Disseminating ethics frameworks for CBM and observing programs based on IK.* As discussed in this review, ethical approaches to documenting observations require that all parties involved discuss and agree on protocols for data collection, documentation, ownership, control, access, possession, dissemination, and long-term storage and use. SAON can help raise awareness about ethical issues related to documentation of IK and can promote adoption of ethics frameworks by the observing networks that participate in SAON.

4. *Supporting the development of platforms that facilitate connection and network building among CBM initiatives.* The Atlas of Community-Based Monitoring in a Changing Arctic is one such platform that will require additional investment to stay up-to-date and to build new services that will facilitate information sharing and network building. Other platforms that can facilitate connection include ArcticHub (www.arctichub.net) as well as regional platforms such as the US Interagency Arctic Research Policy Committee (IARPC) collaborations site (www.iarpccollaborations.org). Each of these platforms has a different intended audience but could be used as a tool to facilitate linkages. SAON can help facilitate connections between platforms (which will also help avoid duplication) and raise awareness about www.arcticcbm.org as a platform dedicated solely to CBM.

5. *Ensuring involvement of CBM practitioner perspectives in SAON working groups and processes.* While CBM is recognized as an important component of Arctic observing, participation by individuals with significant knowledge of CBM has been limited. Recognizing that SAON is largely a voluntary effort without dedicated funding, it may be possible to work towards the establishment of funding mechanisms and to seek external support to ensure that CBM practitioners are able to participate directly in SAON processes and working groups.

Introduction

The Arctic is undergoing rapid environmental and social change. Over the past decades, in situ and satellite monitoring has documented a wide range of ecological changes stemming from anthropogenic warming (ACIA 2005; Jeffries et al. 2014). These changes are creating new challenges for both animal species and human residents of the Arctic (Parlee et al. 2005; Oskal et al. 2009; Knotsch and Lamouche 2010; Hovelsrud et al. 2012; Knopp et al. 2012; Eamer et al. 2013).

Meanwhile, new investments in mining, energy and shipping infrastructure are increasing human impacts on terrestrial and marine ecosystems and leading to new patterns of land and sea use. This has implications for the sustainable long-term use of Arctic resources on the part of Indigenous Peoples, commercial fishermen, and other residents (ICRH 2009; Prowse & Furgal 2009; Clement et al 2013; O'Rourke 2013). There is a growing need for long-term monitoring and observing to better understand the impacts on natural systems and social systems of these varied yet interrelated sources of change (Dallman et al. 2011; Meltofte 2013).

This review seeks to address the need for better information about community-based monitoring (CBM) in the Arctic, drawing on information about past and current CBM and Indigenous knowledge (IK) initiatives in the circumpolar region that has been collected in the online Atlas of Community-Based Monitoring in a Changing Arctic at www.arcticcbm.org. The Atlas and review are part of a larger initiative to ensure that CBM and IK are part of the broader Arctic observing "network of networks" that make up the Sustaining Arctic Observing Networks (SAON).

SAON aims to bring together Arctic research and monitoring communities and make Arctic data more accessible. It was initiated based on a request from the Arctic Council in 2006 identifying a need for "comprehensive, sustained and interdis-

The Arctic Eider Society conducts community-driven research with experienced hunters combining traditional knowledge and scientific approaches to address issues of local concern. Credit: Grant Gilchrist

ciplinary Arctic observations and data management" that could provide insights into Arctic changes and "address the social and human dimension in Arctic observation" (SAON 2014). SAON is led by a board consisting of representatives of the eight Arctic countries, PPs in the Arctic Council, and Arctic Council working groups, along with non-Arctic countries and international organizations. The board is chaired by a representative of the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP) and Vice-Chaired by a representative of the International Arctic Science Committee (IASC).

CBM is one approach to long-term monitoring that has enjoyed a recent growth of interest across the circumpolar region and beyond (Conrad & Hilchey 2011). Arctic residents routinely observe a wide range of environmental and social phenomena as a result of their situated engagement that includes hunting, gathering plants and berries, and traveling on the land; as well as employment in fisheries, mining, and oil and gas development, which also positions them to make routine observations. Arctic Indigenous Peoples' IK includes understanding of environmental dynamics over time, and can provide useful information to assess ecosystem stasis and change. Indigenous Peoples observe multiple indicators, such as wind, ice and snow formation and thickness, and cloud patterns, to help make sense of a dynamic and changeable environment (Eira et al. 2013; Huntington et al. 2009; Krupnik and Ray 2007; Riseth et al. 2011). Their observations of subtle environmental indicators and their familiarity with animal behavior and population dynamics have facilitated successful hunting, fishing, gathering, and overall survival in challenging and changeable conditions, as well as the ability to respond to change (Fidel et al. 2014).

"In Barrow, conditions change on a daily basis. Observation is the biggest tool I use to teach my boys and nephews to continue their hunting practices. We depend on marine resources for food, and we have to make observations about which resources are thriving and which are not."

— Harry Brower, Barrow resident, ICC General Assembly

"Observing and monitoring in our community is ongoing, it happens all the time. Observing the animals, weather, wind, is part of everyday life and just what people do."

— Shari Gearheard, Clyde River resident, Kautokeino workshop

Opposite page: Glaciologist Hajo Eicken walks to a shorefast sea ice monitoring station off Barrow, Alaska, during spring melt. Credit: Matthew Druckenmiller

As an approach to monitoring, CBM offers a range of benefits to communities, researchers, government agencies, non-governmental organizations, and other interested parties. CBM can increase the capacity of communities to document and respond to change, and of scientific researchers to collect year-round data (Johnson et al. 2015). It can support development of new networks and relationships, and can produce data that decision-makers across a range of scales need to make informed decisions about the stewardship of the Arctic in the context of change (Danielsen et al. 2013; 2014).

Depending on design of the project and degree of involvement of community members, CBM can benefit communities, science, and society in a number of ways. The following are just a few potential benefits based on analysis of programs in the Atlas and discussions at three workshops on CBM that also informed our analysis (see review methodology section below for more details):

- Increasing capacity for stewardship and resource management based on both science and IK;
- Offering opportunities for knowledge co-production and adoption of relevant technologies at the community level;
- Supporting IK transmission within the community, including from elders to youth;
- Offering opportunities for residents to spend time on the land pursuing subsistence practices alongside sample collection;
- Providing information that communities and local decision-makers need;
- Providing tools for compiling observations so that they can be shared easily with decision-makers beyond the community;
- Creating opportunities for network building among communities, CBM practitioners, and governments;
- Contributing to understanding long-term trends, including how Arctic ecosystems are responding to various drivers of change;
- Facilitating community adaptation and resilience to current and future change by equipping residents with tools to document and share observations.

In spite of these many known benefits and the overall potential of CBM to contribute to Arctic observing and monitoring, there remains a need for substantial investment in both practice and research to help move the field forward. Huntington and colleagues note that there has not been a significant study of the "accuracy of community-based monitoring of natural resources in the Arctic" (2013:423). A recent report by the National Research Council of the National Academy of Sciences highlighted the need to integrate CBM into research activities (National Research Council 2014). This review is intended to contribute baseline information about the current state of CBM, which may inform development of new monitoring efforts, novel research agendas, and frameworks for application of monitoring to decision-making.

Key terms and definitions

Community-based monitoring

There is no single, widely accepted definition of CBM. This English language term, which is not easily translated into Indigenous languages, has gained the most traction in North America and in Arctic regional policy and practitioner circles, such as the Arctic Council working group Conservation of Arctic Flora and Fauna (CAFF), which has issued a handbook and strategy on CBM (Gofman 2010; Huntington 2008). Somewhat ironically, the term has less currency within Arctic communities than it does within the broader scientific observing community. One participant in the Copenhagen Workshop suggested that the term "monitoring" may not appeal to some IK holders because it does not capture the holistic ways that Indigenous Peoples engage with nature and the interconnections between biodiversity, health and wellbeing for many Arctic Indigenous Peoples and local communities (Nordic Council of Ministers 2015). Although the specific term may be unfamiliar, however, the idea of using local environmental observations to inform decision-making rather than relying on scientific monitoring, alone, has great relevance and interest on the part of many Arctic residents. For millennia, Arctic Indigenous Peoples have identified relevant indicators and made routine observations of their environment, analyzed the information gathered, and communicated, shared, discussed and validated this information in order to make the best decisions. This is monitoring (ICC-Alaska 2015).

Danielsen and colleagues suggest that CBM is "monitoring… undertaken by local stakeholders using their own resources and in relation to aims and objectives that make sense to them" (2013:4). In the Arctic, however, formal monitoring initiatives utilize a combination of outside resources (funding, expertise, labor and technology) and community resources (expertise, labor, observations, adaptations of technology). Another definition suggests that CBM is "a process of routine observing of environmental and/or social phenomena that is led and undertaken by community members and can involve the external collaboration and support of government agencies and visiting researchers" (Johnson et al. 2015).

The task team took the approach that, rather than limiting initiatives to be included in the Atlas based on a particular definition of CBM, the Atlas would be broadly inclusive. This decision is in part due to the fact that there is currently no widely accepted definition of CBM, and that the term has greater currency in North America than in Europe or Russia. Since this task's goal was to begin to inventory initiatives

A weather stations begins to lean with recent snowmelt. Researchers rode snow-mobiles to steam-drill a new 6-meter (20-foot) hole and secure the station. Credit: John Maurer

with relevance to Arctic observing and monitoring, programs could choose to join the Atlas based on self-identification as a CBM initiative or based on self-identification as a IK-based initiative with relevance to Arctic observing. This inclusive approach supported the task goal of identifying the diversity of initiatives that are relevant to monitoring and observing at the community level from a circumpolar perspective.[4]

At a workshop on CBM organized by Oceans North and held in Cambridge Bay, Nunavut, in November 2013, participants discussed whether a more unified definition of CBM was desirable. Some were concerned that a narrow definition may limit the kinds of programs that could receive funding through CBM envelopes, since scientific monitoring methods can be part of a broader portfolio of initiatives that serve the interests of communities. Others felt that if the community of practice did not define CBM, then the risk was that others with less experience may end up defining it on their behalf. One option is to adopt a typology of approaches, such as the spectrum proposed by Danielsen and colleagues from statistical analysis of 107 monitoring programs (2009). This typology comprises five categories of monitoring that involves community members to different extents:

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4. But see "next steps" section for discussion of the need to conduct more focused studies and projects that can advance CBM as a field with broadly accepted standards for community involvement.

Opposite page: A researcher stands looking out to the Beaufort Sea in Barrow, Alaska. Credit Matthew Druckenmiller

This photograph looks out over Barrow, Alaska, the northernmost city in the United States. Credit: Matthew Druckenmiller

CBM definitions proposed by Cambridge Bay Workshop participants

"CBM is an emerging tool that combines science and local knowledge into a system that can persist and be used for comparing regions, change in and between them over time."

— Todd Powell, Manager, Biodiversity Programs, Environment Yukon

"CBM uses local and traditional knowledge from villages where people see the environment, live the environment, and come up with concerns accordingly."

— Cyrus Harris, Tribal Council Member, Kotzebue, Alaska

"CBM is monitoring by the people, for the people."

— Eddie Carmack, Institute of Ocean Sciences, British Columbia

1. externally driven, researcher-executed without any involvement of local people;

2. externally driven, with local people involved in data collection;

3. collaborative with external data interpretation;

4. collaborative with local data interpretation;

5. fully autonomous local monitoring without any involvement of external scientists.

While we do not adopt a single definition of CBM for this review, the following broad points were raised in several of the workshops and inform our analysis:[5]

- Arctic Indigenous Peoples have been observing the Arctic environment for millennia; their knowledge provides a strong foundation for more formal CBM efforts and initiatives.
- Monitoring is distinct from research, which involves collecting data over a finite period of time to address particular questions.
- CBM is distinct from citizen science, which tends to limit public involvement to data collection and is oriented towards addressing researcher-driven questions and data needs (Kennett et al. 2015).
- CBM goes beyond simply hiring field assistants or hunters from the community to participate in data collection. Rather, CBM programs emphasize community engagement and leadership in determining the goals and approaches of monitoring.
- Among the most important features of CBM is that it has the potential to be—and in the best instances is—directed by the community's information needs and goals. It focuses on a scale that is meaningful for people using the data.
- The design phase of a new CBM initiative should consider the potential for community involvement in all stages of the program, including planning, implementation and data collection, interpretation and analysis, dissemination and sharing of data, and application of data to decision-making.
- CBM offers a holistic approach that may utilize different approaches and techniques to meet community needs. Not all programs will necessarily involve community members in all stages of monitoring and use of data.

It should be noted that CBM is usually initiated in order to support communities in attaining a broader goal or set of goals; monitoring in this sense is not an end but rather a means to more informed decision-making. It is therefore linked to governance regimes and practices. In North America, where the term CBM enjoys more widespread use, land claims in northern regions have led to the development of co-management institutions that mandate the use of IK alongside scientific knowledge and create a space for direct involvement of communities in decision-making. Because these institutions are largely absent in the Scandinavian and Russian Arctic, involvement of Indigenous communities in monitoring and observing programs is often decoupled from formal governance arrangements. Further examination of the links between CBM and governance may be useful in refining CBM-related terminologies.

Indigenous knowledge

There are ongoing debates in both academic and applied contexts and among Indigenous Peoples about the appropriate terminology to use when discussing knowledge and indigeneity. The term "traditional knowledge," for example, has been critiqued for setting up a false dichotomy with "modern" knowledge, since all knowledge that is used in a contemporary context is modern, and all knowledge simultaneously has a lineage and history rooted in particular traditions (Turnbull 1997; Barsh 2000). As Julie Cruikshank (1998) has noted, all terms have political connotations that may support reified identity categories regardless of the intentions of users. The term "traditional," which ignores the dynamic and changing nature of all knowledge, may also give the false impression that Indigenous knowledge systems bear no relevance to contemporary society. Partly to address these critiques, other terms such as Indigenous knowledge, or Indigenous science, have been proposed (Barrett 2013; Gorelick 2014).

While the authors involved with this review have used the term "traditional knowledge" (TK) in the past (Johnson et al. 2015), here we adopt the term "Indigenous knowledge" (IK) to reflect a broader consensus that is emerging through ongoing discussions of the Arctic Council PPs that this term better captures the dynamism of Arctic Indigenous Peoples' knowledge. We recognize that the programs that we describe in the review as involving IK do not all use the same terminology, but all do share an interest in engaging and sustaining the sophisticated and unique knowledge traditions of Arctic peoples.[6]

IK is holistic and often encompasses interrelationships between diverse phenomena, including social and environmental phenomena (Bohensky and Maru 2011). There has been a tendency in the Arctic, however, to focus on ecological knowledge in IK studies and research, with implications for

5. A separate SAON task proposed by Victoria Gofman-Wallingford is examining standardization of terminologies related to CBM (Gofman 2011).
6. Note that we have also recently changed the name of the Atlas, previously the "Atlas of Community-Based Monitoring and Traditional Knowledge in a Changing Arctic," to reflect this emerging consensus.

whose knowledge is documented—men's knowledge based on their time as hunters or herders has a larger role in the canon of Arctic IK studies than women's knowledge does (Dowsley et al. 2010; Dowsley 2014). While the majority of programs in the Atlas focus on IK as it relates to the natural environment, many of these programs also contextualize their studies within the broader social and political dimensions of a changing Arctic. There is growing interest in monitoring of social change, including health, industrialization, and social and economic indicators (Berman 2011; Kruse et al. 2011; Vlasova and Valkov 2013), each of which has the potential to engage IK in monitoring programs.

A common misconception about IK is that it lacks a process of validation, which has led to efforts to "integrate" IK into science by subjecting it to a scientific validation process. This approach has been critiqued from a number of angles (Agrawal 2002; Berkes 1999; Nadasdy 1999), and there is now a growing recognition that science and IK are separate but complimentary knowledge traditions, each requiring validation on its own terms (Tengö et al. 2014). In fact, "Indigenous knowledge" is a bucket term that really reflects many diverse knowledge traditions, each of which must be evaluated based on its own system of expertise, much the same way that peer review in the scientific tradition should be conducted by individuals who have a common methodological or theoretical grounding.

IK is validated through a process of testing in practice; what is found to be relevant and consistent over time is passed along to the next generation (ICC 2013). Not all members of an Indigenous community have equal knowledge; those individuals with particular skills in hunting, weather prediction, and other areas of knowledge are acknowledged as experts within their own communities. As Sámi reindeer herder Johan Mathis Turi suggested at the Kautokeino Workshop, Western-trained scientists are not qualified to evaluate IK, so it is important to make specific attributions to IK knowledge sources and to ensure that experienced IK holders review and authorize IK-based observing and monitoring results before they are disseminated.

Local knowledge

While some studies cluster local and IK into the same category (sometimes referred to as "local and traditional knowledge"), we distinguish between them. "Local" knowledge is a somewhat generic term that refers to knowledge generated through embodied engagement or interaction with the local environment. As studies of the sociology of knowledge observe, all knowledge is "local" in that it is created within a particular social context (Turnbull 1997; Bowker 2010). In the context of Arctic CBM, local knowledge holders might include commercial fishermen, tour guides, hunters, bird watchers, and many others who have a stake in and interact with the Arctic environment. In contrast, IK is a systematic way of thinking developed over millennia that continues to evolve through practice and in response to changes in society and the natural environment (ICC 2013).

Some definitions of Indigenous and Traditional knowledge

"Indigenous knowledge is a systematic way of thinking applied to phenomena across biological, physical, cultural and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive and multi-generational observations, lessons and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation… Under this definition, IK goes beyond observations and ecological knowledge, offering a unique 'way of knowing' to identify and apply to research needs which will ultimately inform decision makers" (ICC 2013).

"Traditional knowledge is a cumulative body of knowledge, know-how, practices and representations maintained and developed by peoples with extended histories of interaction with the natural environment. These sophisticated sets of understandings, interpretations and meanings are part and parcel of a cultural complex that encompasses language, naming and classification systems, resource use practices, ritual, spirituality and worldviews" (UNESCO/ICSU 2002).

"[Traditional ecological knowledge is] a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 1999:8).

"The HEROS program primarily draws on local knowledge and observations that can be made by anyone going out on the land regularly and are not limited to only Inuit. It also uses traditional knowledge, because primarily Inuit hunters are the ones sharing their observations. The database is also designed to capture specific comments that hunters would like to make, which may be based on traditional knowledge, such as observations of cyclical dynamics of populations over time."

—Mathieu Dumond, Wildlife Manager, Kitikmeot Region, Nunavut

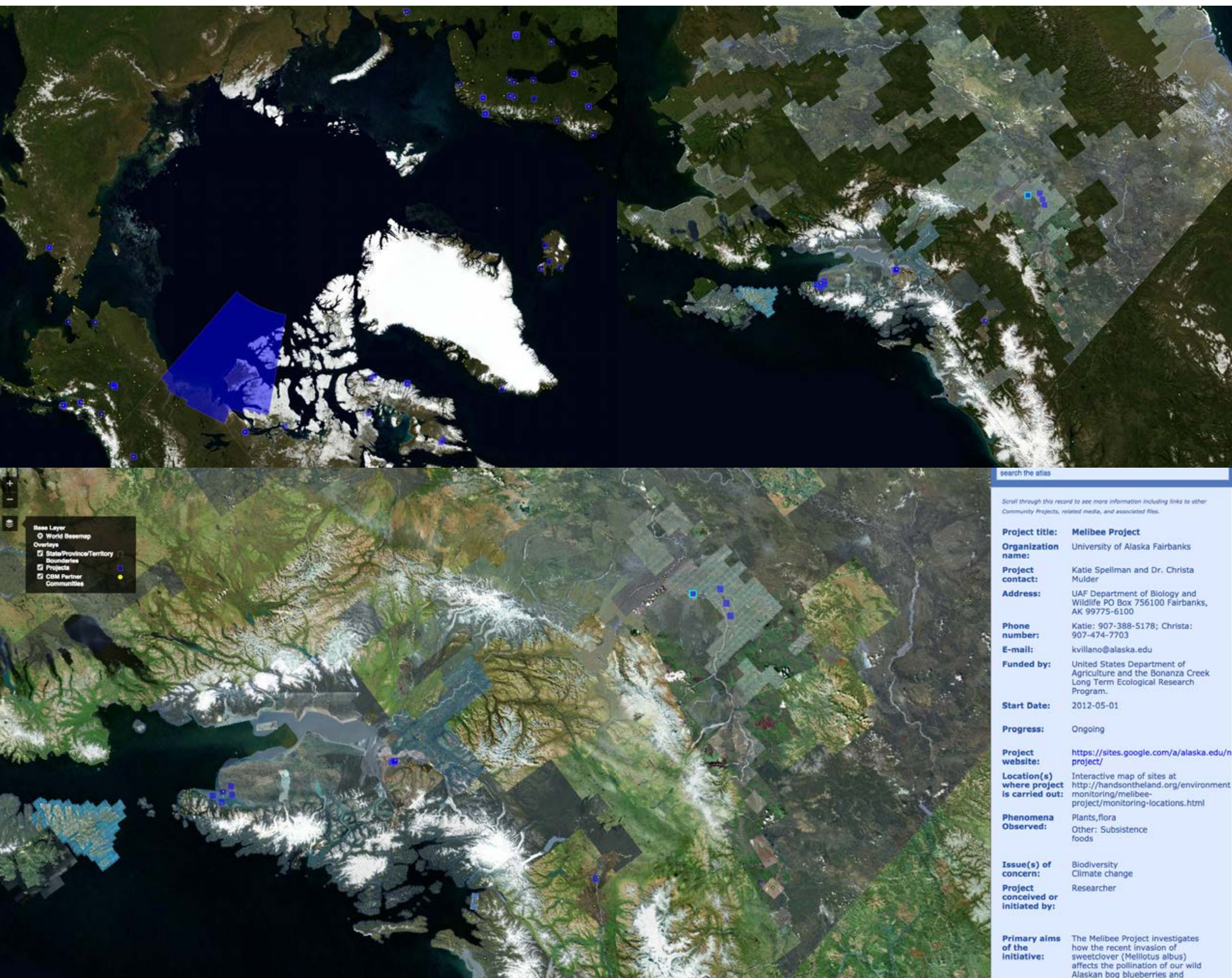
Hemmed in between the Barents Sea and snow-covered hills around it, the dying-out Sami village of Teriberka is one of the most picturesque spots in Arctic Russia on the Kola Peninsula. Credit: Kaisu Raasakka

Background to the review

This review is intended to provide information about the state of Arctic observing and monitoring based on CBM and IK for SAON and the Arctic observing community, including Arctic residents and Indigenous Peoples. Although SAON has identified engagement of CBM and IK as a priority for Arctic observing, the best ways to support robust community participation within the broader field of observing and monitoring remain unclear. At the January 2011 SAON board meeting, the Inuit Circumpolar Council (ICC)[7], the Exchange for Local Knowledge and Observations of the Arctic (ELOKA)[8], and Inuit Tapiriit Kanatami's Inuit Qaujisarvingat: Inuit Knowledge Centre[9] proposed a task to ensure that CBM and IK would be part of the Sustaining Arctic Observing Networks (SAON) and the broader Arctic observing community. The task, "An International Review of Community-Based Monitoring in the Context of the Sustaining Arctic Observing Networks Process," was officially launched in November 2012, with support from a Brown University Voss Interdisciplinary Postdoctoral Fellowship.

The task goals included the following:

- ❄ To begin to develop an inventory of CBM and IK programs across the Arctic;[10]
- ❄ To identify "best practices" from these programs;
- ❄ To develop a set of practical recommendations for how CBM and IK can contribute to Arctic observing in the context of SAON.



Coastal Observation and Seabird Survey Team (COASST) volunteers practice beached bird identification in Dillingham, Alaska Credit: COASST

An online atlas of CBM initiatives (www.arcticcbm.org)

The first step in implementing the task was to create an inventory of existing initiatives—a searchable, online metadatabase (Kofinas et al. 2002) —that could then be analyzed for the review. Based on technical expertise of ELOKA, a web-based atlas infrastructure was developed on the Nunaliit Atlas Framework (http://nunaliit.org) to inventory and map CBM and IK initiatives across the circumpolar North. The Atlas geolocates these various initiatives, visualizes the networks of communities that are involved, and shares metadata provided or verified by program practitioners. The Atlas does not directly store data from any of the projects it maps, but rather captures metadata and directs users to the project-hosted data repositories where they exist.

Because of the limited bandwidth in many parts of the Arctic, an effort was made to minimize the bandwidth speed required to use the Atlas by developing custom programs written in the JavaScript and executed by the user's Web browser. This minimizes the amount of Internet activity required after the initial download of the Atlas.

The Atlas has the potential to serve as an integrative platform for

7. ICC represents Inuit from Alaska, Canada, Greenland, and Chukotka, Russia. For more information, see: http://www.inuitcircumpolar.com.
8. ELOKA facilitates the collection, preservation, exchange, and use of local observations and knowledge of the Arctic. ELOKA provides data management and user support, and fosters collaboration between resident Arctic experts and visiting researchers. For more information, see: https://eloka-arctic.org.
9. Inuit Qaujisarvingat: Inuit Knowledge Centre aims to bridge the gap between Inuit knowledge and western science and build capacity among Inuit to respond to global interests in Arctic issues. For more information, see: http://www.inuitknowledge.ca.
10. The task aimed to identify as many relevant programs as possible given time constraints and the process established for recruitment, as discussed below. IK projects were included in as long as they were focused on documentation of IK-based observations that could be relevant or useful in providing a baseline for long-term observing and monitoring initiatives.

Opposite page: These screenshots of the ArcticCBM website showcase the zooming in feature of the map and the details behind many community-based monitoring (CBM) and Indigenous Knowledge (IK) initiatives across the circumpolar region.

The sun hovers on the horizon in Qaanaaq, Greenland, while NSIDC research scientist Shari Gearheard takes a turn driving the dog team. Credit: Andy Mahoney

environmental, health, and social monitoring. An initial effort to diversify the Atlas produced a map of Inuit Mental Health and Wellness programs (www.arcticcbm.org/health), reflecting this broader framing of social-environmental change.[11]

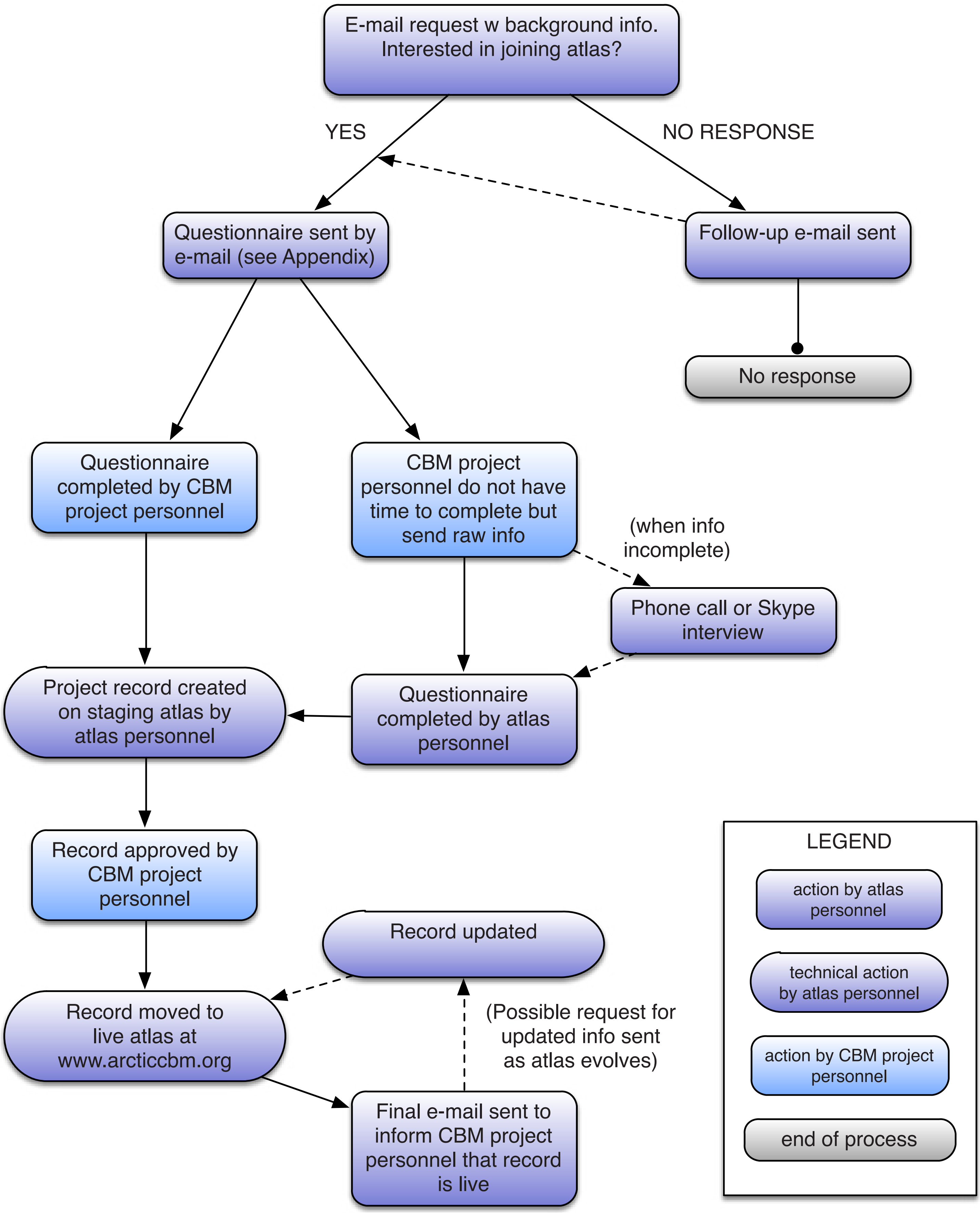
Recruitment methodology

Identification and recruitment of CBM and IK initiatives to join the Atlas involved a number of strategies, including outreach to Alaskan Native Tribal organizations, land claims organizations, research institutes, and Inuit Research Advisors for the Inuit regions of Canada, as well as government and academic researchers engaged in monitoring and observing activities. At the pan-Arctic level, Arctic Council PPs and SAON and CAFF boards were briefed and asked to refer programs. In addition to these direct outreach methods, a search of peer-reviewed and online reports and websites was conducted to identify additional projects and programs.

When relevant projects were identified, an email invitation was sent to the project lead. In order to join the Atlas, project partners were requested to complete a questionnaire that captures metadata about their initiative (see Appendix II). These forms were reviewed and entered into the Atlas by a trained member of the research team to ensure consistency of entries. In some cases, projects and initiatives were identified through public sources such as reports, research articles, and websites, and information was drawn from these sources for the questionnaire. For outreach to Alaskan communities, introductory emails and phone calls helped make connections between current activities being led by community organizations and CBM, since community members were not necessarily familiar with the term (see discussion of terminology above). Phone interviews were conducted to fill in additional

11. Programs in the Inuit mental health and wellness map were not included in the content analysis for this review.

Recruiting Projects for the Atlas (www.arcticcbm.org)



information and, in some cases, as the primary means of data collection. The draft Atlas record was then shared with the project lead who checked it for accuracy and completeness and approved the final version for the Atlas.

The Atlas was designed to be inclusive in order to document the diversity of initiatives that exist that may be relevant to Arctic communities and researchers. One challenge that we recognized from the start was that the term CBM has been unevenly adopted, with greater use in North America and relatively little use in Europe and Russia. Rather than adopting a specific definition of CBM and limiting projects on this basis, we therefore chose to include projects that self-identified as involving residents in monitoring as well as IK projects with relevance to long-term observing. We used a similarly open approach in the geographic range of programs represented, including programs in different parts of the State of Alaska, as well as programs with multiple collaborating communities, as long as at least one was based in the Arctic or sub-Arctic.

Several partners assisted with identification of initiatives. As part of a commissioned study by the European Commission on Arctic "lay, local, and traditional knowledge," the Nordic Agency for Development and Ecology (NORDECO) used the questionnaire to identify CBM and IK programs in Europe that could be added to the Atlas.[12] In North America, the Alaska Ocean Observing System (AOOS) and Alaska Sea Grant contributed programs from Alaska to the Atlas inventory. Appendix I provides a list of programs, projects and initiatives that was current when the report was being finalized; for the most up-to-date inventory, please see www.arcticcbm.org.[13] We continue to recruit and add new programs to the Atlas; if your program would like to be included, please contact: arcticcbm@inuitcircumpolar.com.

Atlas recruitment is ongoing; 81 initiatives were inventoried at the time of this report's writing. There are gaps in the regional distribution of programs in the Atlas, with a relative paucity of programs from Greenland and much of the Russian Arctic. This was due in part to the approach we adopted for identifying and adding programs to the Atlas, which required receiving direct input from programs themselves, rather than using unverified web based information to populate the Atlas.

Questionnaire design

CBM program metadata was collected through a questionnaire (Appendix II). A prototype questionnaire was initially developed by the project partners and tested on a handful of programs, which became the founding programs of the Atlas prior to the official launch. Feedback was incorporated into later versions of the questionnaire. This led to an iterative process where programs were invited to update their entries based on the updated questionnaire. One result of this is that not all programs in the Atlas have completed all questions, however we found that this responsive approach was more inclusive and allowed us to capture information that practitioners prioritized. If funding allows, we plan to request updates to entries in the Atlas on an annual basis.

Review methodology

Once the Atlas infrastructure and initial recruitment were complete, the second part of the SAON task was to develop a review of CBM and IK programs in the Arctic based on the Atlas inventory that included recommendations for how SAON could support the further development and application of CBM. A content analysis of the programs included in the Atlas was conducted, including analysis of trends

Workshop	Location	Date	Host/Funder	Reference
From Promise to Practice: Community-Based Monitoring in the Arctic	Cambridge Bay, Nunavut	19-21 Nov 2013	Oceans North	"Cambridge Bay Workshop"
Symposium on the Use of Indigenous and Local Knowledge to Monitor and Manage Natural Resources	Copenhagen, Denmark	2-3 Dec 2013	NORDECO/ Nordic Council of Ministers' Programme for Co-operation with its Neighbours	"Copenhagen Workshop"
Global Change, Indigenous Community-Based Observing Systems, and Co-Production of Knowledge for the Circumpolar North	Kautokeino, Norway	25-27 Mar 2014	UNESCO, CNRS/MNHN and the International Centre for Reindeer Husbandry	"Kautokeino Workshop"

A citizen scientist makes phenology observations on native berry plants as a part of the Melibee Project. Credit: Sally Endestad.

across a number of multiple choice questions as well as identification of common themes related to program focus, methodology, data management, and issues of concern.

An additional source of input into the review comes from proceedings of the following CBM and observing workshops held in 2013 and 2014, as seen in the chart on page 14.

The analysis draws on and synthesizes content from the inventory and workshops to identify common themes, examine good practices and challenges, and develop recommendations for how the Arctic observing community can support CBM.

Due to time and funding limitations, CBM program practitioners were not involved in analysis of Atlas metadata or interpretation of "good practices" for the purpose of this review. The authors hope that additional work will be undertaken by the CBM community to bring together CBM practitioners, IK holders, and community and collaborating researchers to identify best practices.

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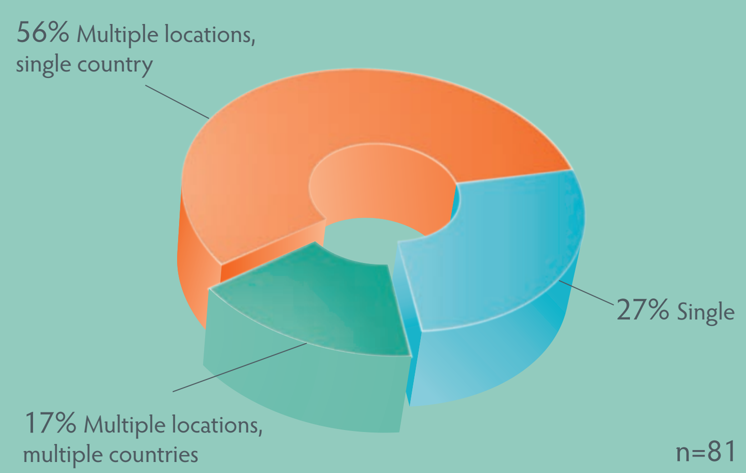
12. Some programs identified through this process were not entered into the Atlas inventory because they chose not to join, did not respond to invitations, or did not provide enough information to demonstrate involvement of community members. Of a total of 73 European CBM and IK initiatives identified, 37 were included in the inventory. The authors acknowledge the assistance of Teis Adrian, Tero Mustonen, Kia K. Hansen, Rodion Sulyandziga, Níels Einarsson, Polina Butylkina, Weronika A. Linkowski, and Elmer Topp-Jørgensen in identifying CBM and IK programs in Europe.
13. With support from Polar Knowledge Canada, we are in the process of enhancing representation of terrestrial monitoring programs in Canada in the Atlas, using records from the Polar Data Catalogue to identify relevant initiatives and following the same recruitment process described below.

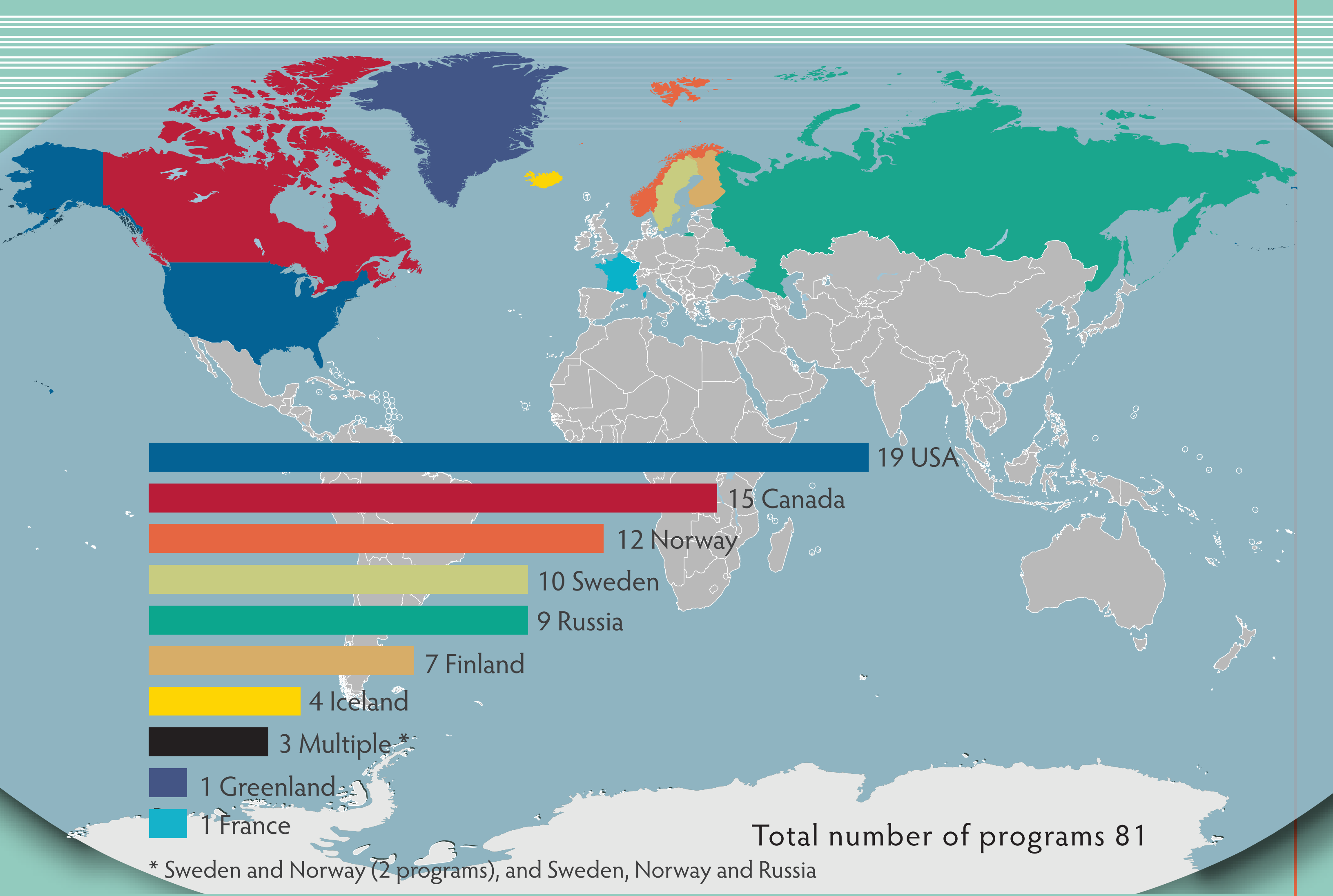
General Overview of Programs in the Atlas

As of September 2015, the Atlas contained a total of 81 CBM and IK programs across the circumpolar region. Of these, 37 were recruited through the European Commission study by NORDECO[14], and 9 were recruited through a collaboration with Alaska Ocean Observing System (AOOS) and Alaska Sea Grant. Programs had their institutional headquarters based in the following countries:

Twenty-two (22) programs were carried out either in a single community or in a single geographical area (such as a fjord or bay) with a single coordinating organization. One of these planned to expand to a second location within the same country; another was part of a network but each project had its own goals and leadership. The majority of programs (45) were carried out at multiple locations in a single country. Of those programs carried out in multiple countries (14), nearly all were designed around commonalities, such as belonging to a particular region (e.g. Bering Sea), or a shared identity that spanned

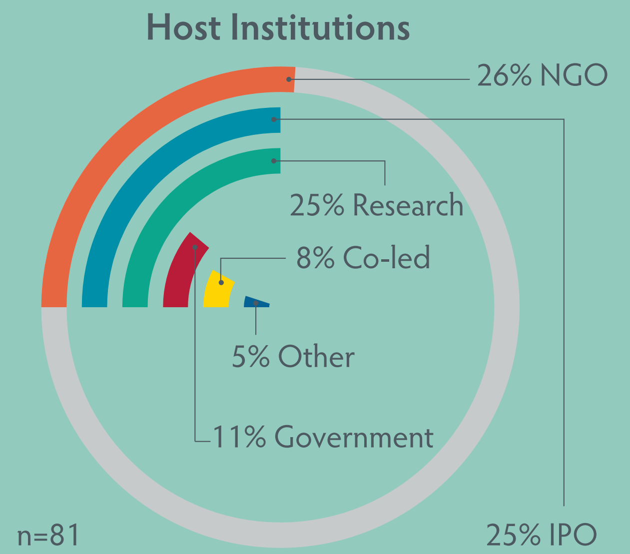
Single vs. Multiple Locations





country boundaries, as in the case of Sámi or Inuit, or common land use and subsistence activities such as reindeer herding.

The programs in the Atlas were hosted by a variety of institution types, including Indigenous Peoples' organizations (IPOs—including Indigenous government institutions, higher education institutions, and non-governmental organizations); non-governmental organizations (other than those included in the IPO category); research institutions/academia; government agencies (national, territorial, county, and municipal); and other institutions, including museums (3) and the private sector (1). Of the initiatives that were co-led, the majority (9 out of 10) involved an IPO as one of the hosts.



Program start date and current status

We have knowledge of the start-up year of 74 of the 81 Atlas programs. Most programs were established within the last 10 years (2005-2014) (54 programs), nearly half of which were started within the last 5 years (2010-2014) (25 programs). Twenty (20) programs were established more than 10 years ago.

The majority of the programs were currently active (58), with nearly half listed as "ongoing" (36) and an additional 22 "in progress."[15] Around a quarter were "completed" (19), and four (4) listed their status as "temporarily on hold due to a lack of funding."

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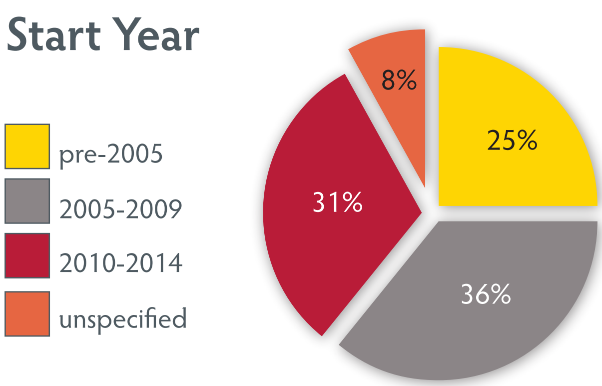
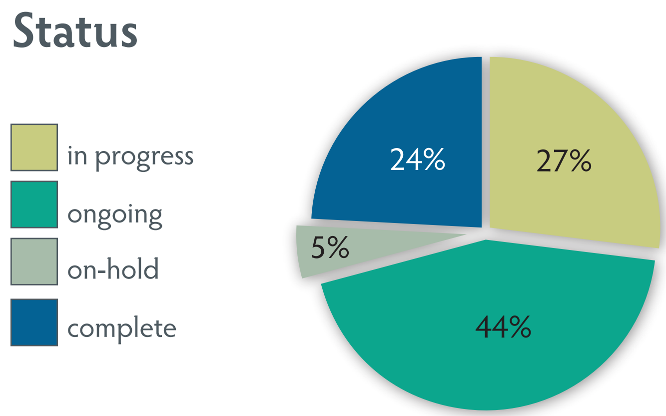
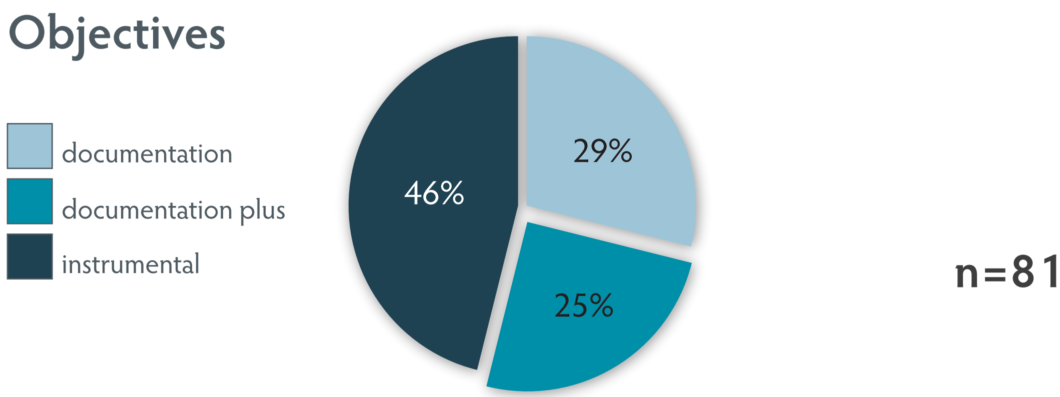
14. This study utilized the metadata collection form developed for this atlas, and carried out an initial analysis of the responses collected for European programs.
15. The difference between an "ongoing" and "in progress" project is that for the latter, an end date is anticipated, while for the former, there is no anticipated end date.

Program Details







Program Objectives

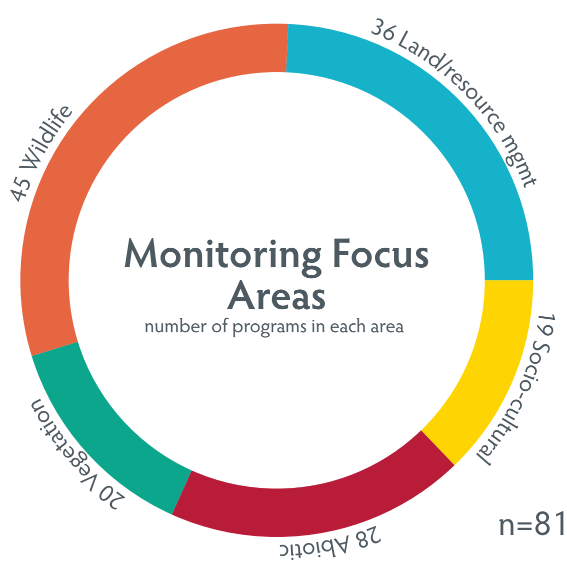
Thornton and Scheer (2012) distinguish between IK studies that seek to document knowledge ("documentation") and those that seek to improve natural resource management ("instrumental"). By reviewing the goals, methods, and data sharing and use protocols of the programs in the Atlas, they can be divided into three categories:

1. Those that seek only to document knowledge or observations ("documentation") (24 programs)

2. Those that primarily document, but do so with an interest in application to improve management ("documentation plus") (20 programs)

3. Those that are directly linked to decision-making mechanisms (or with documented use in these contexts) and are designed around use of data ("instrumental") (37 programs). This means that a significant majority of the programs (56) were designed with the goal of providing data and observations for management or decision-making

The attributes that programs in the Atlas monitored fell into five broad focus areas, with the majority of programs observing phenomena in two or more categories. This pluralistic approach within programs reflects the broad nature of socio-environmental change in the Arctic, as well as the focus of many CBM initiatives on supplying observations for the purpose of improving management and decision-making.



❈ Management of land and resources (36 programs) in relation to, e.g., reindeer husbandry, hunting, commercial fisheries, tourism and industrial development

❈ Wildlife (45 programs) including species-specific programs on insects, shellfish, fish, birds, and mammals

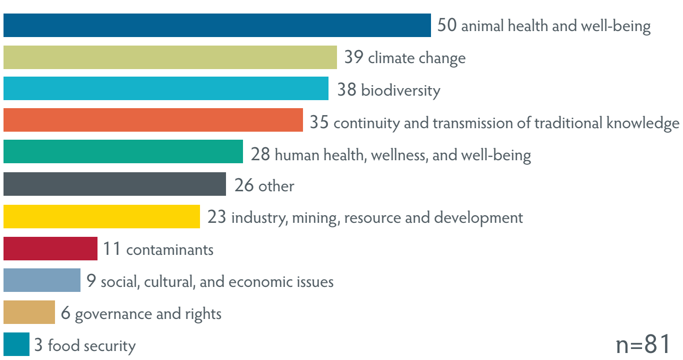
❈ Vegetation (20 programs) including fungi and plants

❈ Abiotic phenomena (28 programs) such as water, air, snow, ice, wind, and weather

❈ Socio-cultural attributes (19 programs) such as health, wellness, and language and IK transmission. (Note that not all programs that engage IK as a source of observations were included in the "socio-cultural attributes" category; instead, programs that explicitly sought to strengthen capacity for IK transmission were counted in this category, along with human health-related programs)

Issues of concern

What overarching issues is your monitoring program concerned about?

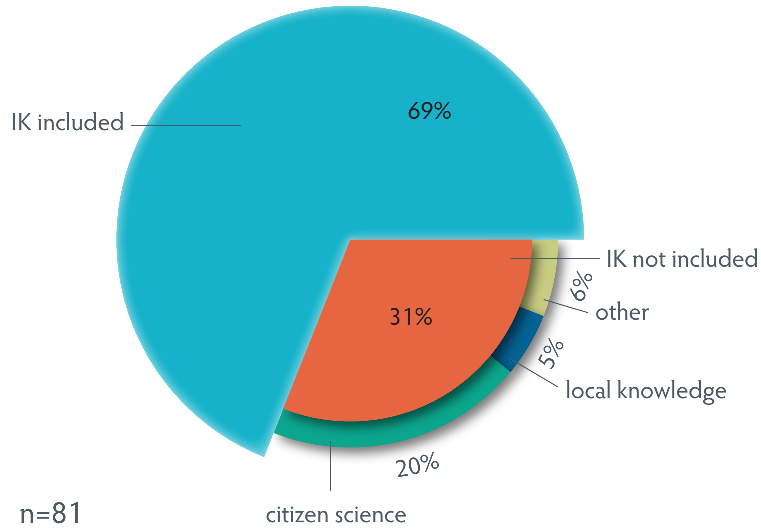


The questionnaire asked programs what overarching issues their monitoring program was concerned about and provided non-exclusive, multiple choice options that included (with the number of programs that responded positively to each item in bracket): biodiversity (38); contaminants (11); climate change (39); industry, mining and resource development (23); animal/fish/marine mammal wellness and well-being (50); continuity and transmission of IK (35); human health, wellness, and well-being (28); food security (3); governance and rights (6); social, cultural, and economic issues (9); and "other" (26) (a write-in category).

The role of Indigenous knowledge

Out of 81 programs, the majority (56 programs) engaged IK in some capacity. Of those that did not (25 total), 16

Role of Indigenous knowledge

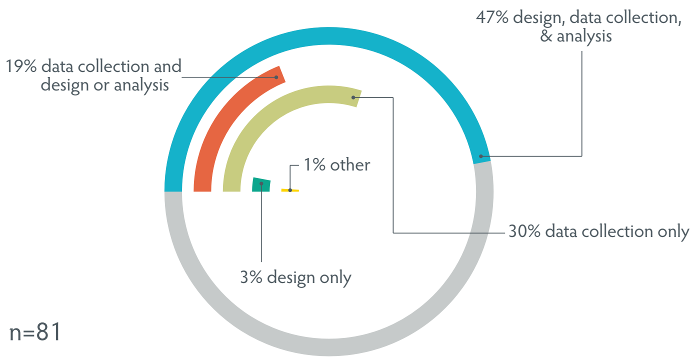


were citizen science initiatives (sensu Shirk et al. 2012) that engaged volunteers in collecting data for scientific research and monitoring purposes. The majority of these citizen science initiatives were not based specifically in the Arctic, but were either active over the entire country (6 programs), or in regions outside the Arctic, such as southern parts of Alaska (8). Four (4) programs documented local knowledge of fishermen, farmers, and hunters, while two (2) programs engaged recreational hunters in monitoring terrestrial mammals using transects. Two (2) citizen science programs utilized whale-watching tours to collect scientific data.

Of the 56 programs and projects that indicated that IK was involved, 41 provided specific explanatory text that allowed for additional analysis. Many of these projects were designed to elicit IK to inform natural resource management processes or to understand where conflicts between traditional use and mining and oil and gas developments may be emerging; in these projects, methods primarily focused on using interviews, focus groups, and participatory mapping exercises. It was, however, often unclear from the information provided how much community members were involved in shaping research goals or analysing the information gathered. (See discussion of IK under "good practices section" below for additional information).

Twenty-three (23) programs in the Atlas documented IK and scientific observations for the purpose of supporting decision-making based on multiple evidence bases, or multiple ways of knowing (see "co-production" section below for specific examples). In several cases, programs collected IK through interviews or oral histories alongside more conventional approaches to environmental monitoring.

Community Involvment

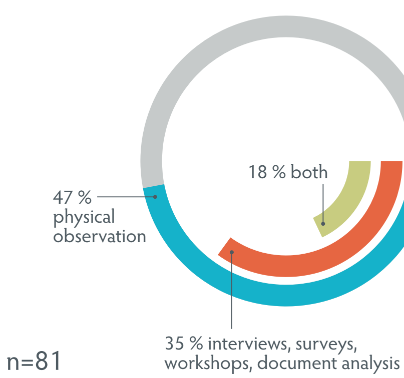


Involvement of community members

The questionnaire asked, "What components of the project/initiative involved community members?" It provided multiple-choice categories that included project design, data collection, and data interpretation and analysis, as well as a write-in "other" category. Thirty-eight (38) programs involved community members in program design, data collection, and analysis. Sixteen (16) programs involved community members in data collection and either program design or data analysis. Twenty-four (24) programs only involved community members in data collection, whereas scientists undertook program design and data analysis. Two (2) of the programs involved community members in the project design stage only. For one (1) program, community involvement was limited to setting up instrumentation for scientists.

Data collection methods and approaches

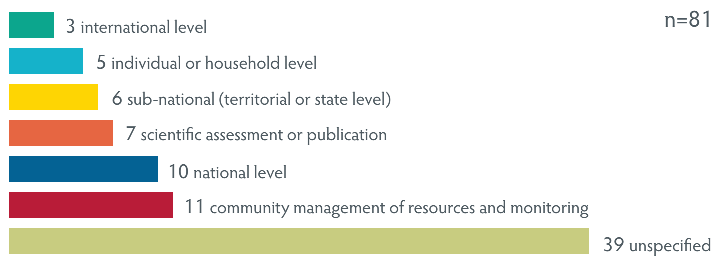
Data Collection Methods



Programs in the Atlas collected data in a variety of ways. Broadly speaking, these can be clustered into two approaches. One approach involved collection of physical or biological observations, samples, and measurements (38 programs). Of these, 18 programs used GIS, GPS, or specialized instrumentation to collect observations and data. The other approach utilized more qualitative methods (28 programs), including use of interviews, surveys, workshops, with some programs also reporting use of documentary analysis (12 programs). Only 15 programs combined these two approaches, using physical observations and interviews, workshops, surveys and/or documentary analysis.

Intended scale of information use

How are data used?



The inventory questionnaire included the open-ended question, "How are data used?" Of the 42 programs that responded, five (5) described a primary use at the individual or household level, eleven (11) described use for local or community management of resources and monitoring, and six (6) described contributing to sub-national (territorial or state level) uses. Ten (10) mentioned contributing to national level monitoring and management, and three (3) described contributing to transnational management and assessment processes. Seven (7) mentioned a primary use of information for scientific assessment or publication; while this response does not reflect a specific scale, it suggests a more national or international audience rather than a local one.

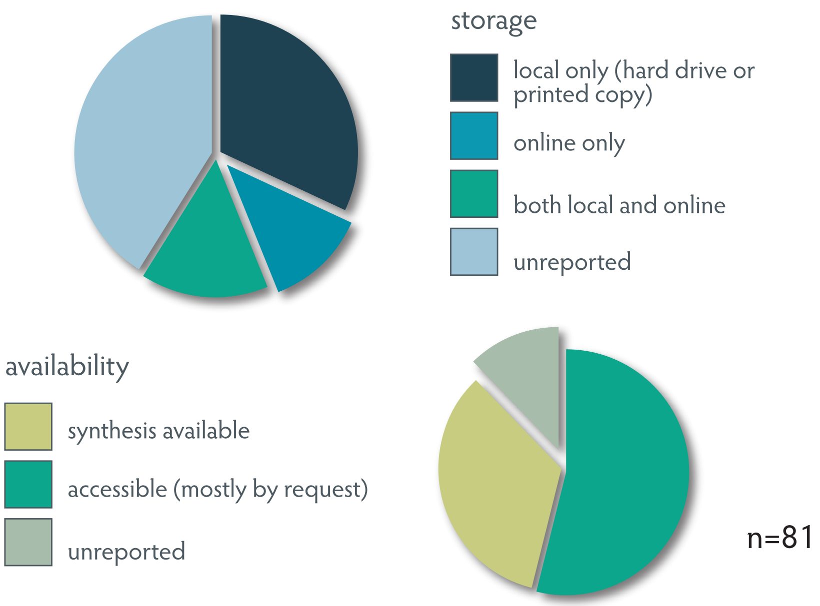
Data management

Data management information was collected via an open-ended question ("How are data collected, shared and stored?"), so not all programs shared the same information. Many programs noted that decisions about whether to make information public or not were made in consultation with communities, particularly for programs that involved IK. In these cases, some sensitive information was managed and held locally and other information released in synthesis.

Analysis of the Atlas database revealed a variety of different approaches to how data are collected, shared, stored and used. Some programs stored data locally (in either print copies or local hard drives or institutional databases), while others used

Opposite page: Ashore, snowdrifts surround fishing boats in Sanikiluaq, Nunavut Canada. Credit: Chris McNeave

Data Storage & Availability



online storage options (in either summary versions or full data storage that was either protected or public). Of the 48 projects that reported their data storage methods, 26 only stored data locally (23 on a local hard drive only and three in print and on a hard drive); while 10 stored data only online. Of those that only stored data online, three offered full public access, five (5) stored all data but offered only a synthesis to the public, and one stored all data but did not make any public. Twelve (12) programs stored data both locally and online, with two offering full access to data and 10 posting synthesis reports.

The majority of the programs made data and information accessible to the public (43), although many only by request. Twenty-seven (27) programs made some data available, often in synthesis reports. Eleven programs did not make the data public, although a few had plans to make some data accessible in the future. An independent analysis of data accessibility using the Atlas found that of 79 programs analysed, 14 programs (18%) made their data accessible (defined as downloadable, in a format conducive to use, i.e. not pdf files) (Murray et al. 2014).

Specific Issues

Many programs in the Atlas were designed to respond to the need for better information in the context of socio-environmental change. In this section, we highlight a number of critical issues organized by theme that programs in the Atlas were designed to monitor, including development and extractive industry, contaminants, and biodiversity and species monitoring. Within each issue area, we offer examples of programs drawn from the Atlas.

Monitoring the impacts of development and extractive industry

Increasing interest in oil, gas, and mineral deposits in the Arctic is leading to growing concerns about the cumulative impacts of land use change, increased shipping, seismic testing, infrastructure development, air pollution, potential oil and gas spills, invasive species, and other development related impacts. When established as an independent source of monitoring, CBM can offer communities a way of tracking the impacts of development, and can guide land use decision-making to minimize impacts on fragile ecosystems, human health, and subsistence use. A number of initiatives listed in the Atlas are concerned with monitoring related to these diverse impacts of extractive industries. Combined with the impacts of climate change and long-range transport of contaminants, these changes create cumulative effects that require careful design of monitoring programs.

Development and land use change

Monitoring and observing based on IK is closely linked to land use practices. For Arctic Indigenous communities whose land rights are not secure, a number of initiatives are underway to document traditional land use alongside changes in land use patterns due to industrial development, mining, oil

"Oil companies are coming in and making projects, going into where the plankton are. There should be wildlife monitors and marine mammal observers, but how can oil companies watch themselves? People up here should do the monitoring, not the industry that comes here."

— Inuvialuit Settlement Region resident, Cambridge Bay Workshop

"With OCS [outer continental shelf] offshore developments, a lot of it is scary, the possible threats – it helps to have communities be a big part of the research, getting rid of insecurity by not having the sense of foreignness to the research. Becoming more familiar with how information is developing, being able to use IK in effective ways. I think there is a real psychological benefit."

— Alex Whiting, Kotzebue IRA

and gas, and exploration. CBM can provide frameworks and tools useful for monitoring land use change that threatens traditional use for hunting and herding activities. A number of programs in the Atlas focus specifically on ensuring that Indigenous rights are protected and that appropriate consultation practices are utilized in the context of increasing industrialization and increasing shipping traffic in the Russian Arctic and Sámi regions.

A community member is scanning the sea off of Greenland for seabirds as part of the PISUNA program. Credit: Finn Danielsen

In Russia, land rights of Indigenous groups remain largely unrecognized, and there are few legal frameworks to regulate relations between industry and Indigenous communities. The project "Supporting democratic participation of northern Indigenous peoples in the Russian Federation," led by the Centre for Support of Indigenous Peoples of the North, developed maps that can be used to monitor the intersection of industrial activity and Indigenous land use in Kamchatka (oil and gas) and Yakutia (mining). The goal of the project is to support dialogue between the two groups and to promote the adoption of international standards for protection of Indigenous rights. A similar initiative by the Association of Nenets People of Yasavey, "Monitoring of development of traditional Indigenous land use areas of the Nenets Autonomous Okrug," developed a GIS map database of Indigenous land use and industrial development in the Nenets Autonomous Okrug (NAO).

Land use studies can also reveal a broader set of issues and uses that require sustained monitoring. A large-scale land use study in Murmansk, Russia by the Snowchange Cooperative revealed multiple pressures on traditional Sámi lands, including mining and salmon fishing tourism. These various pressures on traditional use territories suggest that to serve community needs and interests, monitoring must be viewed holistically and developed to examine multiple sources of pressure and change in the landscape. As Tero Mustonen, Director of Snowchange, explained: "Multinational corporations don't speak Sámi language, but they do speak the language of mapping of land use" (Copenhagen Workshop 2013).

In Sàpmi, the traditional Sámi territory of Norway, Sweden, and Finland, mining and mineral development poses new threats to reindeer herding pastureland. The Protect Sàpmi Foundation was established in Norway to help protect land rights of Sámi herders by mediating between industry and Sámi, working to ensure Free, Prior and Informed Consent (UN 2008) is maintained in development projects and to develop long-term agreements that incorporate thorough impact assessments.

Hydro-electric development

The Arctic Eider Society is a collaboration between researchers at the University of British Colombia and community members

Opposite page: Two ships survey the Arctic continental shelf, an underwater extension of surround coastal areas. The U.S., Russia, Canada, Denmark, Norway, and Iceland hold claim over certain regions of the Arctic, where melting ice frees up access to large caches of energy resources. Credit: Patrick Kelley

In some areas of Greenland, hunters control access to resources through local means. Moreover, merely by living on the land, using the resources, and observing their environment, the communities notice changes in the resources. Greenland's PISUNA Community-Based Monitoring (CBM) program was designed to build upon and strengthen existing informal community-based observation and management systems. Credit: Finn Danielsen

in Sanikiluaq, Nunavut. The project monitors the cumulative impacts of climate change and hydro-electric development on sea ice. This includes studying the dynamics of freshwater plumes under sea ice, as well as studying impacts on wildlife such as entrapment of eiders and belugas. Methods engage both Inuit knowledge and western scientific knowledge, including collaborative field research, interviews, and GPS referencing to integrate qualitative observations and quantitative data. The program is expanding to include communities in eastern Hudson Bay.

In Jokkmokk, Sweden, the Snowchange Cooperative led a project to document the impacts of a series of hydroelectric reservoirs, focusing in particular on the Luleå watershed. The project used oral history interviews, place names, maps, diary entries, and photos to document the observations of Sámi reindeer herders and other community members. The project results were used in a variety of ways, including in the development of academic publications and a monograph and by contributing to the Arctic Biodiversity Assessment (Meltofte 2013); they can also be used as a baseline for long-term monitoring of change due to development in the region.

Contaminants

Contaminants from industrial and agricultural activities outside the Arctic are transported into the region through air and ocean currents (AMAP 2014). CBM programs concerned about the impacts of contaminants on human health engage community harvesters in sample collection; samples are then sent away for lab-based contaminant analysis. In Alaska, a number of regional non-profit corporations run programs focused on environmental health; while they may not adopt the term CBM, some nonetheless are engaged in sample collection for contaminants monitoring and involve community members in the process. In Canada, the Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in country foods. The NCP is a best practice model that supports capacity building and ensures participation of Arctic Indigenous peoples in management, research development and implementation, as well as information dissemination (Krümmel and Gilman 2015). The NCP includes a CBM funding envelope that directs resources towards community-led efforts to examine the impacts of long-range, trans-boundary pollut-

> "We started the bucket brigade because after the 2012 well blow-out, they didn't have any air monitoring stations that were updated or even effective, and it took them 32 days to cap the well."
>
> — Martha Itta, Administrator, Native Village of Nuiqsut

ants. Information from the NCP is used to inform international efforts to reduce or eliminate contaminants, such as the Stockholm Convention on Persistent Organic Pollutants and the Minamata Convention on Mercury.

One initiative that has been partially supported by the NCP and other agencies is a beluga harvest monitoring program in the Inuvialuit region of western Canada. Collaboration between Inuvialuit hunters in the Mackenzie Delta, the Fisheries Joint Management Committee co-management board and government scientists led to the program's establishment in the 1970s. Data collection was standardized in 1980, whereby hunters provided biological and hunt-related data to monitors (Inuvialuit) who were hired throughout the region as seasonal monitors for the duration of the whaling season (Harwood et al. 2015). Monitors collect samples from harvested belugas that are evaluated for health, including stress indicators and the presence of contaminants. Because belugas are an important source of food as well as a sentinel species high up in the food chain, this CBM program contributes information that is important for community health and well-being as well as for broader ecosystem-based monitoring and cumulative effects monitoring.[16]

Alaska Community Action on Toxics (ACAT) was founded in December 1997 in response to requests for technical assistance by Yup'ik villagers on St. Lawrence Island to address environmental contaminants arising from the presence of military sites; villagers had become concerned about long-term health impacts related to the sites. Since then, ACAT has worked with St. Lawrence Islanders and coastal villages in the Norton Sound region to monitor the health effects of atmospheric transport of PCBs and pesticides, former military installations, and flame retardant chemicals found in common household items. ACAT also runs a community-based research institute that offers an intensive, college accredited course in environmental health and monitoring for northwestern Alaskan communities.

The Native Village of Kotzebue's program on organic nutrients and contaminants focused on the spotted seal and shellfish, important species for maintaining food security in Kotzebue. The program looked at nutrient and contaminant concentrations and changes to these concentrations resulting from different food preparation methods. The knowledge of residents informed which species were studied, as well as contributing to sample collection and directly to the analysis of food processing methods. While designed as a research project, results may be used to provide baseline information for a longer-term monitoring program.

Species monitoring and biodiversity

A number of initiatives in the Atlas were designed to monitor issues related to subsistence species, while others focused more broadly on biodiversity monitoring (which

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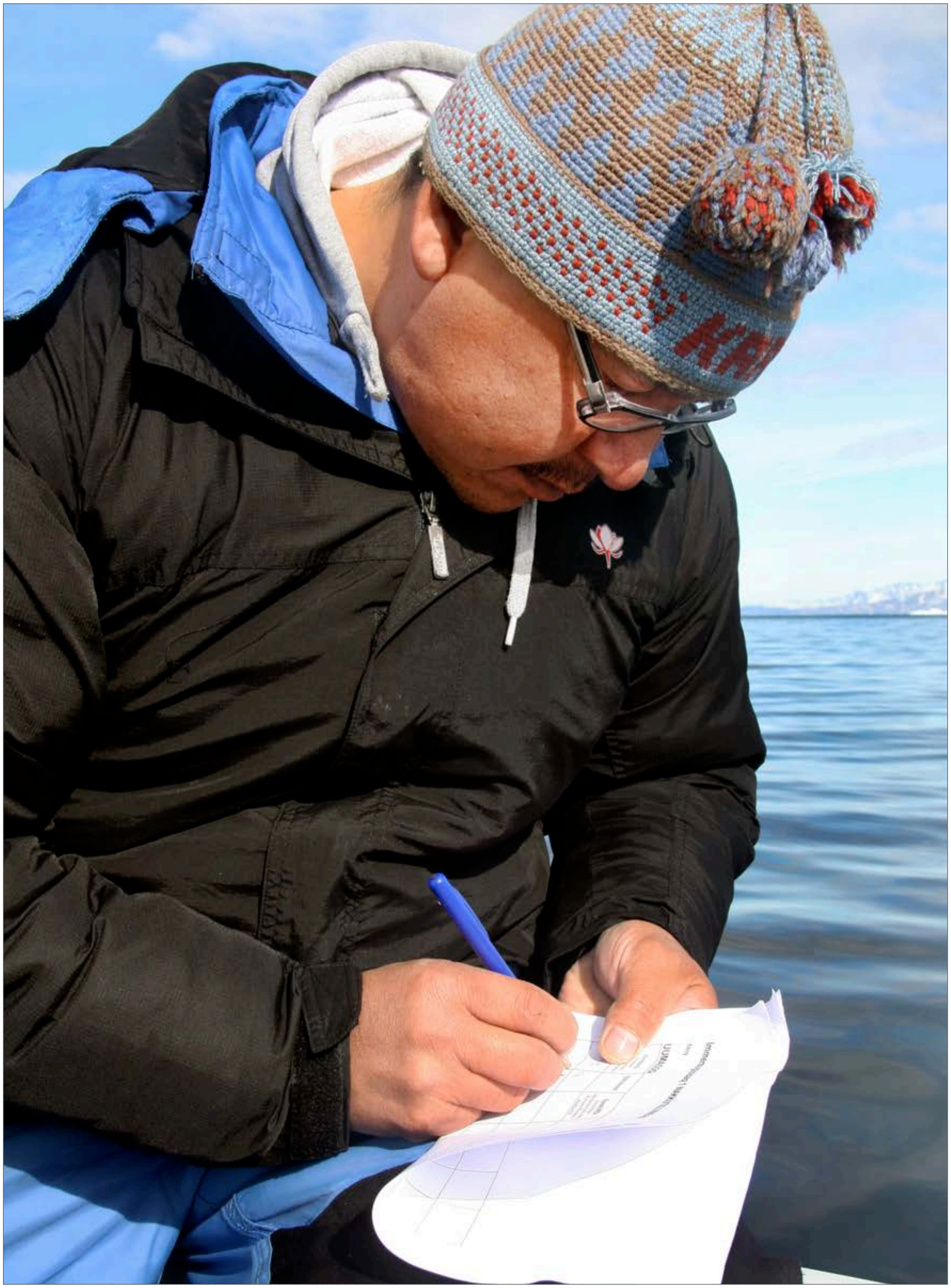
16. This program was not included in the Atlas at the time of this review because it was included in a web atlas of CBM initiatives in the Inuvialuit Settlement Region developed by the Inuvialuit Settlement Region's Community-Based Monitoring Program (ISR-CBMP): http://jointsecretariat.ca/resources/community-based-monitoring-program/

The sun sets over sea ice in Barrow, Alaska. Credit: Matthew Druckenmiller may include species that are not central to subsistence). While not all of these initiatives formally articulated the links between species and biodiversity monitoring and food security, a number of them were designed specifically to link observations to decision-making about ecosystem and species management to ensure access to country foods (in Canada and Alaska), or to better understand links between reindeer pastoralism and biodiversity (in Sámi regions). The Nomadic Herders project, which engages herding communities in Mongolia, eastern Russia, and Norway, aims to increase the understanding of how changes in biodiversity are affecting reindeer herding societies, and to develop resilience and adaptation strategies in the context of land use change. Ájddo, a project of the Swedish Sámi Parliament and the Swedish Biodiversity Centre, documented the relationship between reindeer herding and biodiversity within mountain-to-sea landscapes in Sweden. Additionally, observations from several Snowchange projects contributed to CAFF's Arctic Biodiversity Assessment.

Many programs monitored particular species based on CBM or IK methods, including those that are important to subsistence such as seals, salmon, bowhead whale, walrus, moose, and caribou, and predators including brown bear and polar bear. The project "Traditional knowledge of the native peoples of Chukotka about walrus," initiated by the Association of Traditional Marine Mammal Hunters of Chukotka (ATMMHC), collected IK of Chukotka residents about walrus behavior, feeding areas, migration patterns, and traditional use of walrus by native peoples. The project was conducted in conjunction with the Eskimo Walrus Commission. ATMMHC also engaged biologists and native residents of Chukotka in collaborative monitoring of walrus haulouts.

Other monitoring programs in the Atlas utilized citizen science approaches to engage residents, hunters, and tourists in collecting information about the abundance and distribution of various species. For example, both the Coastal Observation and Seabird Survey Team (COASST) and the Kachemak Bay Shorebird Monitoring Project utilize volunteers to collect data related to sea birds, including beached birds and oil presence (COASST), and population abundance and migration (Kachemak Bay). Discover Alaska's Whales engages tourists who pay to participate in whale watching expeditions to collect observational data on humpback whales, while Wild North Whale Watching uses tourist whale watching boats in Iceland to collect data on cetacean species.

Finally, a number of programs in Alaska monitored invasive species that threaten native habitats and ecosystems. The Kachemak Bay Research Reserve (KBRR) engages volunteers to collect data on the invasive European green crab and invasive tunicates in near-shore waters near Homer, Alaska. Also in Alaska, the Melibee Project investigates how the recent invasion of sweetclover (*Melilotus albus*) affects the pollination of wild Alaskan bog blueberries and lowbush cranberries.



A community member from Qaarsut, Greenland, writes down his observations of Canadian Geese as part of Greenland's PISUNA Community-Based Monitoring (CBM) program. Over the past decade, the population of Canadian Geese has risen sharply, threatening to out-compete the Greenland White-Fronted Geese. Therefore, suggestions were made to extend the Canadian Geese hunting season. In 2015, the Department of Fisheries, Hunting and Agriculture announced it would expand the hunting season from two to seven months. Credit: Finn Danielsen

Opposite page: The sun sets in spring over sea ice at Barrow, Alaska. Credit: Matthew Druckenmiller

Good Practices

In this section, we highlight good practices demonstrated by a number of programs in the Atlas related to CBM program development and implementation. In calling these "good practices" instead of "best practices," we acknowledge that additional work needs to be done to consider whether there are common best practices that apply to all CBM initiatives across the circumpolar region. These practices reflect the report authors' analyses of program attributes as well as commentary from the workshops, and are not intended to be a "consensus" perspective. We believe that CBM would benefit from a process to identify best practices based on direct input from CBM practitioners, particularly those that are residents of Arctic communities and IK holders; unfortunately, such a process was beyond the scope and funding available for this review.

For each good practice area, we highlight several programs from the Atlas as examples. The programs included under each "good practice" were selected based on self-reporting by programs of their own practices, rather than through an external verification process. Additionally, programs included here are intended to be representative rather than comprehensive; it is likely that additional programs from the Atlas as well as many programs not yet included in the Atlas exemplify or apply these practices.

The approaches highlighted in this section may not be relevant for all CBM initiatives. Rather than view these practices as a checklist that all CBM programs should adhere to, practitioners could consider using these as a starting point to discuss with community members and potential data users what elements and outcomes of a CBM program are important to them. For example, one of the "good practices" considered here is the need to consider technology needs and gaps and to engage Internet and communication technologies (ICTs) and geospatial

In Greenland, a community member fills in a summary form, which is a fundamental element of the PISUNA program since it encourages self-evaluation of local observations and knowledge while promoting discussion. Credit: Finn Danielsen

technologies to advance community monitoring needs. Not all CBM initiatives utilize geospatial technologies or ICTs, and some may specifically choose not to do so because of a lack of reliable Internet access or to avoid reliance on equipment that cannot be maintained locally (Danielsen et al. 2014).

At the end of each "good practice" section, we include a number of recommendations for practitioners to consider; these are drawn from discussions at the three workshops and from analysis of programs in the Atlas. The recommendations are compiled together in a table format as Appendix III at the end of the report.

Build capacity

Communities have very different levels of capacity to initiate, participate in, and benefit from monitoring initiatives. Capacity is linked to diverse factors such as the presence of local and Indigenous institutions, interest and enthusiasm of community members, availability of funding, and previous experience with CBM methodologies. One critical aspect of capacity is the ability of communities to give clear guidance to researchers about what their needs and requirements are for monitoring programs (Cambridge Bay Workshop). Capacity is also related to the degree of CBM activity—with no CBM activity, there is little opportunity to build or demonstrate capacity. Because interest in research and monitoring in the Arctic is growing quickly, community capacity to keep up with this interest is increasingly strained as institutions and local experts are tapped for multiple projects (Kautokeino Workshop).

Formal CBM initiatives require multiple skill sets to be successful, including knowledge of how to travel safely on the land; knowledge of how community members relate to and understand the environment and environmental change; and technical skills including knowledge of scientific approaches to monitoring. The latter also requires knowledge of funding opportunities, data management, and reporting. Capacity for sustained monitoring therefore requires leadership of individuals who can wear different hats, connecting IK and observing practices with institutional frameworks for scientific monitoring, funding, and enabling data and information sharing (Cambridge Bay Workshop).

Opposite page: A woman kneels at the floe edge in Barrow, Alaska. Credit: Shari Gearheard

Left: Dr. Nicolas Cullen is making measurements in the snow (temperature and density profiles) while a local expert, Koni, is steam-drilling. The wooden box contains batteries that run the instruments on the weather station in Greenland. Credit: John Maurer

Some of the diverse skill sets useful for establishing successful monitoring programs include:

- ❄ Ability to understand what different actors may hope to get out of a monitoring program
- ❄ Cultural knowledge specific to the community where the program will be implemented
- ❄ Knowledge of territory, animal behavior, subsistence practices and strategies, and survival skills based in IK
- ❄ Understanding who has expert knowledge and how knowledge and observations are shared within the community
- ❄ Understanding of scientific monitoring tools and techniques
- ❄ Grant writing, reporting and communication skills
- ❄ Oversight and management of personnel
- ❄ Knowledge of how to safely travel (including first aid) and how to operate boats, snowmobiles, and other modes of transport (such as dog sleds) in a northern environment
- ❄ Language skills
- ❄ Knowledge of how to capture, store, report/share, and preserve data over time

While CBM initiatives benefit from strong local institutional capacity, they can also contribute to capacity building and knowledge transfer. This may involve working with local institutions to hire and train staff to manage various project functions and activities such as those listed above. Additionally, individual skill development can be supported through workshops and trainings in areas such as research and monitoring. When monitoring initiatives involve IK, they can provide opportunities for IK transfer within the community.

Researchers at universities located outside the Arctic initiate many monitoring and IK research projects. While CBM does not have to be initiated locally to meet locally important goals and objectives, there appears to be a strong link between local institutional capacity and the ability to engage meaningfully in long-term monitoring. Local and Indigenous institutions may be better able to develop monitoring programs that reflect local needs and priorities and can therefore be sustained more easily. As the Arctic continues to change, fostering resilience in Indigenous Arctic communities will require investing in Indigenous institutions that will be able to support leadership and capacity for research, monitoring, and decision-making (Henshaw 2012).

Among Arctic Indigenous Peoples, the Sámi stand out as having more than 30 years of institution building in higher education. Sámi University College, for example, is the lead institution for a number of IK and observing programs focusing on reindeer herding practices and observations of change. The Árbediehtu (which means Sámi IK) project, coordinated by Sámi University College, focused on methods and technologies for data collection, documentation, preservation and storage, and protection of árbediehtu. A main goal was strengthening capacity of local Sámi communities and institutions to engage in best practices related to árbediehtu research projects.

Opposite page: Students from Kugluktuk, Nunavut, harvest berries from plots as part of the Kugluktuk Berry Monitoring Project, a collaboration that involves researchers from the University of British Colombia, the Kugluktuk High School, the Nunavut Department of Environment. Credit: Sarah Desrosiers

Regional co-management institutions also contribute to capacity building that can facilitate community involvement in monitoring and observing. In Alaska, the Eskimo Walrus Commission (EWC) represents 19 coastal walrus hunting communities, supporting community involvement in walrus research, monitoring, and regulatory processes. EWC is an intermediary institution that can interface with national and state institutions, regulatory processes, and local community needs, with a focus on increasing capacity of community engagement. For example, through a partnership with the U.S. Fish and Wildlife Service, EWC serves as a liaison with communities involved in walrus harvest data and sample collection and encourages scientists to include local hunters in research activities. Commission members from the 19 communities also complete an annual questionnaire based on observations related to harvesting activities, and relevant environmental, social observations and concerns in their home community.

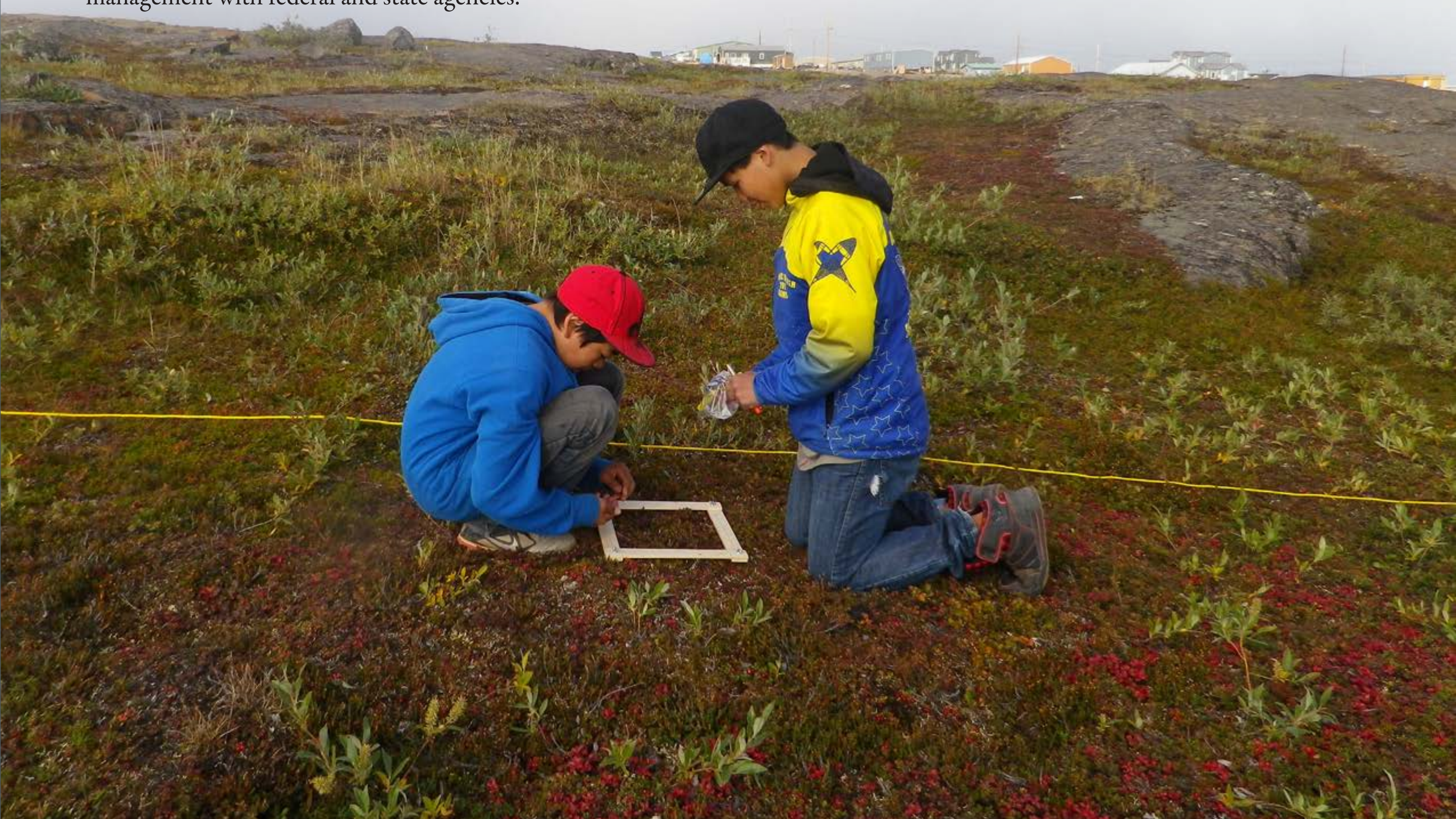
Also in Alaska, the Native Village of Kotzebue's Environmental Program conducts monitoring and research focused on the ecology of Kotzebue Sound, which provides the majority of subsistence resources for residents. Two major drivers of change for this area are loss of sea ice and warming water, as well as the ongoing development of the Chukchi Sea Oil and Gas Lease Area 193. The program has focused on building local capacity to conduct environmental assessments, to educate and inform Tribal members about environmental issues, and to represent the Tribe in discussions related to environmental management with federal and state agencies.

In Canada, hunters' and trappers' organizations are community-level institutions that serve as focal points for all research and monitoring related to wildlife. Some communities have established their own research institutions, such as the Ittaq Heritage and Research Centre in Clyde River, Nunavut. Ittaq is an institutional home for a number of projects focusing on CBM and observing of change. Community-level institutions with capacity to support research and monitoring can help gauge community interest and determine relevant monitoring indicators, and can help build effective monitoring partnerships between communities and researchers.

Recommendations: Building capacity

❄ Community: During program design, project leaders should consider the potential impact on local and Indigenous institutions. Does the program include funding to hire and train local staff in various roles, both for data collection and interpretation as well as for program administration and management?

❄ Community/national: Capacity building goes both ways: it is important to build the capacity of scientists to work with communities and not only the other way around. Including a skill mapping exercise in the planning phase can help identify opportunities to share and transfer skills among collaborators.



Community members from Pangnirtung, Nunavut, set up a winter camp as part of a project to implement a community-based fishery monitoring program and stock assessment framework for Arctic Char. Department of Fisheries and Oceans Canada developed the project in collaboration with the Pangnirtung Hunters and Trappers Organization and the community of Pangnirtung. Credit: Zoya Martin

"It's not enough for scientists to just go parachuting into communities. They really need to spend time. Training programs to teach people to conduct their own sampling and monitoring programs is really important. Scientists often want to just go in and collect data and leave – there has to be capacity building included in research design so that people can participate fully in the research."

— Pamela Miller, Alaska Community Action on Toxins

"We have to make sure that also traditional knowledge of Indigenous Peoples is respected and used. In this respect, it is very important to build our own knowledge institutions."

— Mikhail Pogodaev, Association of World Reindeer Herders (Kautokeino Workshop)

❄ Pan-Arctic: Permanent Participant (PP) organizations of the Arctic Council are already involved in representing CBM within SAON and Arctic Council working groups, but capacity and resources limit their involvement. Increasing involvement of PPs and IK holders involved with monitoring programs will enhance Pan-Arctic discussions on observing and monitoring. Additionally, further linkages between sub-national, national and regional level representative structures will facilitate greater exchange of information about relevant new and ongoing monitoring initiatives.

Engage IK and co-produce observations

Many CBM programs draw on both IK and conventional scientific approaches and technologies. Engaging diverse knowledge systems to address research questions is referred to as "co-production" of knowledge, an approach that is gaining traction in the Arctic and beyond (Armitage et al. 2011; UNESCO 2012). The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), for example, has adopted a "multiple evidence base approach" that requires engaging complementary knowledge systems to assess and monitor biodiversity (Copenhagen Workshop; Tengö et al. 2013). Co-production can engage different knowledge systems in different ways. For example, an IK holder may have a question based on their own observations of local environmental phenomena that scientific researchers may not know to ask; scientific methods or technological approaches may expand the scale of observation beyond what an individual can observe (for example, into the microscopic level of toxins analysis or the macro level of satellite data over a wide regional area).

Co-production, like all forms of scientific collaboration, works best when based on solid relationships built on trust. In many parts of the Arctic, Indigenous communities have a mistrust of government decision-makers and scientists based on past experience. Community members may be concerned about potential misuse of IK by non-residents. Scientific research has often played a role in management decisions that were imposed on communities, particularly in relationship to wildlife management (Kautokeino Workshop). In spite of this, there are many examples of projects based on relationships of trust and mutual respect that are supporting a new paradigm of research in the Arctic.

IK can guide and shape how monitoring priorities are derived. The project "Alaskan Inuit Food Security Conceptual Framework: How to Assess the Arctic from an Inuit Perspective," is an Inuit driven project. The project methodology comes from IK. Through this project, Inuit knowledge holders define Alaskan Inuit food security, identify 57 drivers of food security and insecurity and provide a conceptual framework to guide how to assess food security. Part of this process includes identification of baselines needed to assess vulnerabilities related to food security. The final report suggests many monitoring needs related to the identified drivers and emphasizes that IK holds monitoring methodologies. In this project, then, monitoring is an outcome of a broader participatory process; IK creates a framework in which monitoring needs and priorities are determined, rather than being viewed as simply an information source.

A father and son monitor oceanography through a seal breathing hole, as featured in the film People of a Feather. Credit: Joel Heath

IK may be solicited to help with selection of study sites or geographical boundaries for monitoring, or to determine the best location for instruments such as weather stations or sea ice monitoring stations. Alaska Community Action on Toxins (ACAT) decided to take samples to study contaminant levels at former military sites in the spring after an elder suggested that contaminants may be mobilized at that time of year due to ice gouging. In the Silalirijiit Project (or Kangiqtugaapik (Clyde River) Weather Station Network), IK holders helped identify the best places to install three weather stations based on their knowledge of weather patterns and information needs. An additional component of the project documented elders' weather forecasting knowledge and organized workshops for elder-youth exchange of weather knowledge and skills. The project used both scientific and IK methods to co-produce new knowledge: drawing on the Inuit observation that weather was more changeable in the springtime than in the past, meteorologists identified a decrease in weather persistence due to climate change (Weatherhead et al. 2010).

Finding the best ways to document IK for observing and monitoring purposes remains a challenge, since this requires capturing contextual information relevant to IK holders as well as considering project goals for sharing and synthesizing data more broadly. One issue for programs seeking to make data available and relevant across scales is the question of how to document information from IK holders in a way that is meaningful locally and does not limit the kinds of observations community members can make (Nadasdy 1999). The SIZONet Community Sea Ice Observing Network, which collects data on local weather conditions, sea ice conditions and sea ice related events, activities, and hazards, addresses this by asking local observers/IK holders to record what they deem important and relevant to local ice use and cultural activities.

EALÁT: Reindeer Herding in a Changing Climate was an interdisciplinary Polar Year project initiated by the Association of World Reindeer Herders (WRH) to address herders' need for better data and information for responding to the global and environmental changes. It focused on the integration of reindeer herders' knowledge with scientific research and analysis of their ability to adapt to environmental variability and change. One component of the project involved using satellite observations and geographic information systems (GIS) to increase the ability of herders to monitor land change and land use change in their pasturelands. It drew on previous work to identify what instruments and measurements would be most useful to reindeer herding monitoring over the long term, and aimed to collect data that could simultaneously validate NASA satellite imagery while also helping establish a long-term, place-based monitoring system of reindeer herders' pastures and societies (Maynard et al. 2011).

One of the sub-projects of EALÁT led by Sámi researchers, CEAVVI, used interviews, linguistics analysis, and diary entries to examine how Sámi reindeer herders in the Kautokeino region of Norway monitor snow as part of their herding management techniques. Herders used diary entries to record phenomena such as weather, snow conditions, wind, air, herd behavior, and GPS location. Physical measurements of snow conditions were also taken using scientific equipment and snowpack modeling analysis (Eira et al. 2013). This project utilized a co-production approach to better understand and document how Sámi herders observe and monitor snow conditions using their own knowledge system (Kautokeino Workshop).

The Evenk Community-Based Transdisciplinary Observatory (BRISK) in eastern Siberia was established based on observations of climate and environmental change by Evenk herders. It uses methods designed collaboratively by herders, climatologists, anthropologists and ethnobiologists. Herders record daily observations, and an anthropologist and an Indigenous co-researcher collect additional data using pictures, videos, and interviews. The project also includes knowledge exchanges between Indigenous communities through the organization of nomadic workshops (Kautokeino Workshop). Depending on the agreement of the Evenk community members involved, some data are shared for scientific purposes with climatologists, geographers, biologists, snow specialists and with other Indigenous communities.

In some cases, co-production is facilitated through in-person interaction of a research team that involves both scientists and IK holders. In other cases, co-production is mediated through a technological interface and does not occur in real time. For example, both the Local Environmental Observer (LEO) Network and Sea Ice for Walrus Outlook (SIWO) use web interfaces to geolocate observations contributed by local observers as well as sharing information contributed by sea ice scientists and other experts.

Recommendations: Engaging IK and co-producing observations

- ❄ Community: Project leaders should ensure that community members, including IK holders when relevant, are centrally involved in setting goals for CBM programs based on co-production; consider how different types of observations, including those based on both IK and scientific measurement, could contribute to meeting these goals.
- ❄ Community: Sound relationships for knowledge co-production are built over time and usually involve knowledge exchanges that are both personal and professional. Rather than simply organizing workshops for formal exchange, hands-on activities to build relationships could be considered. This could include traveling together on the land as well as hosting northern community members at the institutional homes of collaborating scientists.
- ❄ Regional: Co-production may be particularly relevant for regional observing and monitoring initiatives that require diverse sources of information to meet multiple user needs. In regionally designed programs, the specific interests of each community involved should be considered, keeping in mind that interest, relevance, and availability of IK to monitoring and observing may vary between communities, even in the same region.
- ❄ National/pan-Arctic: Arctic residents should be recognized for their ability to engage in monitoring on an ongoing basis as initiators of and/or contributors to CBM programs. Their observations, including those by IK holders, should be recognized as an important source of observ-

The research team takes a travel break near Clyde River, Nunavut, Canada. Credit Shari Gearheard ing information in national observing and monitoring plans and in Arctic Council working group initiatives, including CAFF's Circumpolar Biodiversity Monitoring Programme (CBMP), as well as in SAON activities.

Recognize and engage diversity within communities

Although communities are internally diverse, there is a tendency in the literature and program design of CBM programs to treat them as homogeneous. For example, programs that engage IK may fail to consider the gendered nature of knowledge. The majority of the programs in the Atlas did not specify a gender focus. Only two programs were designed to focus on women's knowledge, both in the Sámi regions, including Birgen: Traditional knowledge and Education in Reindeer Husbandry and Transferring and using Traditional Ecological Knowledge among Sámi Reindeer Herding Women. These programs focused on network building and documentation of IK, but not specifically on monitoring of change. Other programs, such as berry monitoring, also may engage women's knowledge but did not specifically name this as a goal. This relative lack of attention to women's observations follows a larger trend in IK research in the Arctic, which has focused more on men's knowledge of hunting and reindeer herding. Women's knowledge of skin preparation and handling and plant knowledge, however, is highly relevant to observing and monitoring.

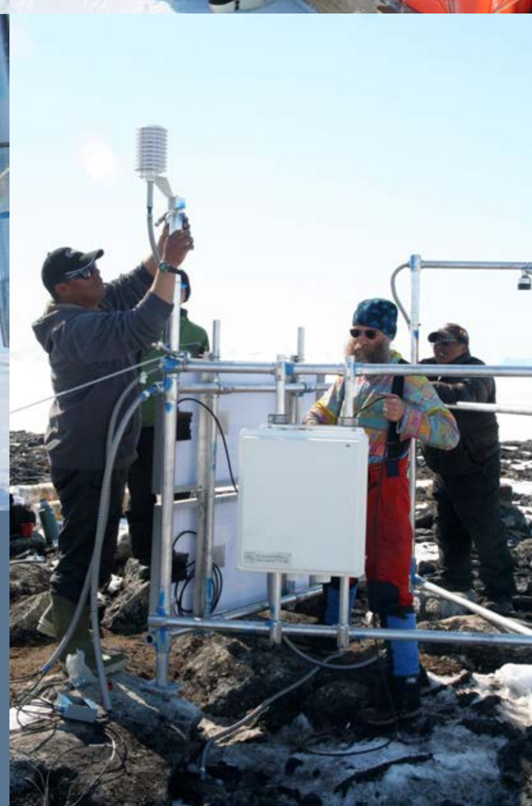
CBM programs present an opportunity for youth training in both scientific and IK methods of observation, however only five programs in the Atlas (three in Canada, one in Alaska, one in Sweden) included a focus on youth. The Ájddo project in Sweden was based on an interview model in which trainees collected IK from the reindeer communities. Elders were interviewed together with a younger reindeer herder; the interviews were therefore viewed as an opportunity for both the collection and transmission of data.

The Kugluktuk Berry Monitoring Project, established in Kugluktuk, Nunavut, by researchers at the University of British Colombia, aims to support intergenerational knowledge transfer about culturally important berry species by working with elders and high school aged Inuit youth. Youth participate in snow measurements and berry harvesting, counting, and weighing; elders participate in oral history workshops to facilitate transfer of environmental and plant knowledge to younger generations.

Another program, Avativut ("our environment"), delivers high school science education in Nunavik that uses long-term berry and ice monitoring to engage high school aged students in hands-on science and technology learning activities. Data are collected according to standard protocols developed by scientists; and a web portal is used to offer instruction in monitoring techniques, collect and share data, and host IK videos of elder interviews conducted by students.

The Silalirijiit Project

Clyde River, Nunavut



Installing weather stations for the Silalirijiit Project. Credit: Shari Gearheard

Opposite page: Shorefast sea ice off Barrow, Alaska. Credit: Qinugan Roddy

"My role has been a facilitator and interpreter for both sides. I interpret the western science for local people and the local science for western people. Our projects are really bringing together both sets of knowledge to exponentially result in fuller answers that address priorities of both community members and scientists."

— Alex Whiting, Kotzebue IRA

"There needs to be a balance between knowledge that is based up here and knowledge according to Euro-centric ways. A big part of that needs to be addressed in CBM, where there is actual collaboration, not just using northerners in a token way as a way to get funding."

— Nunavut resident, Cambridge Bay Workshop

Recommendations: Engaging diversity

- Community: There is a need for more attention to women's observations and knowledge in CBM programs. Programs should consider how women's knowledge can be utilized in monitoring and observing.
- Community: While some programs incorporate youth training as part of CBM and IK initiatives, overall, this is an under-developed aspect of community participation in observing and monitoring. Programs should consider how they can incorporate youth engagement.
- Regional: Regional authorities should consider how programs can be linked or expanded to other communities in order to capture diversity and provide opportunities for capacity building and knowledge mobilization and transfer.
- National: Funding programs for CBM activities could create special categories or incentives for participation by social groups that are traditionally under-represented in CBM activities, including women and youth.

Adapt technologies to respond to information needs and infrastructure inequities

Unequal access to information and communications technology (ICTs) remains a critical challenge across the circumpolar region. This issue is particularly problematic when corporations or outside actors seeking access to northern resources have better information access than communities seeking to monitor the potential impact of development (Kautokeino Workshop). ICTs can be used as a way to document IK and traditional land use practices, and to understand how environmental and economic changes are prompting adaptation over time. Technology can therefore contribute to monitoring in support of continued traditional use.

A number of programs in the Atlas incorporated GIS tools to help fill in information gaps about land use change in the context of development. Others adapted technologies to capture local observations in ways that could be more easily aggregated or visualized for decision-makers.

The Igliniit (Trails) project brought Inuit hunters and geomatics engineering students together to design, build, and test a tool to assist hunters in documenting their observations of the environment (Gearheard et al. 2010). The goal was to design a product that would allow hunters to record their observations in context during their regular, routine trips on the land. The tool that was developed includes a GPS equipped personal digital assistant (PDA) and portable weather station that measures temperature, humidity, and pressure, and logs location every 30 seconds. Hunters could also input observations they made along the way using a touch screen interface in English and Inuktitut. The hunters determined what they wanted to be able to track; this included observations of animals, geographical features such as types of sea ice or rockslides, and travel hazards such as cracks in the ice. Hunters also carried digital cameras that took geo-referenced images. Although this project focused in particular on developing the technology for Inuit hunters, Igliniit has wide ranging applications in natural resource management, harvest studies, hazards mapping, search and rescue, and cultural inventories.

The Harvest and Environmental Records Operational System (HEROS) was a pilot initiative developed through a collaboration between staff members of the Government of Nunavut's Department of Wildlife and community members in Kugluktuk. It features a specialized computer with a touch-screen interface located at the Wildlife Office where hunters can record their observations and harvest levels of 19 terrestrial species. The purpose of the initiative was to develop a system to collect these observations in aggregate so that they could be used to inform the Government of Nunavut's wildlife management decision-making.

The Nunavut Wildlife Management Board's Community-Based Monitoring Network uses portable, hand-held computers to collect wildlife harvest and environmental observations from harvesters while they are on the land. A community data clerk collects the information and uploads it onto a centralized database. The data will be used to inform wildlife management practices locally and regionally within Nunavut. The project is in a pilot phase involving communities of Sanikiluaq, Arviat, and Cambridge Bay, with the potential to scale up the initiative based on lessons learned from the pilot.

Harvesters in Cambridge Bay, Nunavut, receive training on how to use MESA handheld computers to track harvesting information for the Community-Based Monitoring Network organized by the Nunavut Wildlife Management Board. Credit: Peter Evans

In some cases, concerns about long-term sustainability, technology maintenance, and low bandwidth or little computer access have led initiatives to use "pen and paper" and other low-tech approaches to data collection. For example, the Piniakkanik sumiiffinni nalunaarsuineq (PISUNA) initiative in Greenland asks community members to enter observational data on a standard calendar.

Recommendations: Adapting technologies

- Community: Programs should consider plans for long-term data ownership, processing and transfer in project design. Information about wildlife harvesting can be sensitive, and data processing requires specialized knowledge and equipment. Programs that use information and communication technologies (ICTs) to geolocate harvest-related information should negotiate long-term data ownership and management from the outset and should prioritize protection of sensitive information.
- Regional/national: To defray the high costs of ICTs, including the need for upkeep and maintenance, programs could consider involving third party technology developers and managers; this would distribute costs across multiple users and programs and help transfer or share technologies. Another option worth considering is whether similar technological approaches have been developed for other projects that could be adapted through collaboration and network building. Hosting, interoperability, and standardization are all issues that need to be considered when exploring various options.

Scale observations and support network building

Because responding to Arctic change requires decision-making across scales, there is a need for monitoring data that can inform local, regional, national, and pan-Arctic decision-making. One of the characteristics of CBM, however, is that it is often initiated for community monitoring needs and purposes. Aggregation of data based on IK presents challenges for retaining community control over data as well as the potential loss of important contextual information (Agrawal 2002;

"I use a small computer with GPS and carry it on many of my trips to record observations or harvest information. It is helpful to see trends – for example, we are seeing many more grizzly bears here now, a species we are not used to seeing on the island. Making observations raises questions: why are they here? Is there a lack of food on the mainland? Also we can see what impacts mining or industry has on the land and the animals that we harvest here. We are concerned about the caribou migration; after mining company went in, the caribou would not cross roads; today no caribou there. Taking all that information on a computer is nice because we can look at it in the future; its part of ensuring that our children will have access to what we enjoy."

— Cambridge Bay Resident, Cambridge Bay Workshop

Mustonen and Lehtinen 2013). In spite of these challenges, many communities in the Arctic share characteristics and could benefit from collaborative initiatives that involve comparing and aggregating data as appropriate. Additionally, communities may be interested in contributing data to inform decision-making at different scales.

The formation of networks is a critical part of disseminating and/or scaling CBM related information. Networks serve as conduits for the flow of knowledge and information both within communities as well as between them, and between community institutions and actors and institutions outside the community. There are many different possible network formations depending on the purpose and goals of a network, which may include: sharing and exchanging information through a distribution list or web portal; in-person exchange of knowledge and information through field research, workshops, or working groups; or coordinating and sharing funding sources. Additional functions that CBM networks might serve include:

- ❄ Allowing communities to exchange knowledge, experiences and best practices
- ❄ Educating a new generation of natural resource managers that can use both information from IK and science in a respectful manner
- ❄ Trying out new ideas in practice
- ❄ Elevating the status/increasing the visibility of CBM
- ❄ Informing the work of intergovernmental bodies such as the Arctic Council, for example its working groups CAFF/CBMP and AMAP
- ❄ Supporting community-based efforts for knowledge mobilization
- ❄ Generating research by Indigenous Peoples
- ❄ Providing direct access to information for Indigenous communities
- ❄ Identifying community experts who can participate in national and international meetings and interface with the wider observing community
- ❄ Conducting peer reviews of monitoring and science done by other communities
- ❄ Developing shared indicators that are meaningful to communities
- ❄ Facilitating the use of standardized data collection and documentation protocols to allow data to be compared and aggregated as appropriate

Developing CBM networks will require consideration of information and advocacy needs at different scales and across different regions. These include, for example: capacity building and training on relevant methods and exchange of IK approaches at the community level; increased dialogue with national government bodies about CBM and discussion of how local monitoring can be supported and inform national monitoring goals; and articulation within international bodies such as the Arctic Council, including considering how CBM can inform ongoing assessments and monitoring by Arctic Council working groups (Copenhagen Workshop; Nordic Council of Ministers 2015). An additional consideration for the development of networks is the need to respect information that cannot be shared and programs that do not want to participate in sharing information.

Successful networks leverage shared experiences and focus on common resources and concerns. For example, the project "Transferring and using Traditional Ecological Knowledge among Sámi Reindeer Herding Women" focused on network building among Sámi women from Norway and Sweden through workshops, focus groups and seminars. Collecting data was a secondary activity managed by the Sámi women involved. Other successful networks address management of a shared resource, such as the Bilateral Walrus Monitoring project, which focused on connections between Chukotka and Alaska in relation to walrus harvesting, and the Arctic Borderlands Ecological Knowledge Co-op, which contributed to co-management of the Porcupine caribou herd.

The Sea Ice Monitoring Network included: Barrow, Alaska; Clyde River, Nunavut; and Qaanaaq, Greenland. Local residents helped install monitoring stations. Elders and hunters exchanged observations about sea ice knowledge and how sea ice is changing. The data gathered established a baseline for each community, and also allowed researchers to identify significant differences in the thermal regimes of sea ice near each community (Mahoney et al. 2009). Additionally, sea ice expert working groups were established in each community to document the observations. The network of communities also held sea ice knowledge exchanges through which residents of each community were able to visit other communities in the network for participatory observation and knowledge exchange (Gearheard et al. 2006; Huntington et al. 2009). This documentation and knowledge exchange enabled greater understanding of the meaning and use of sea ice in the three communities (Gearheard et al. 2013).

Opposite page: The nomadic Chukchi community of Turvaurgin camps in spring. This reindeer brigade thrives in the Lower Kolyma, Republic of Sakha-Yakutia, Russia. Credit: Tero Mustonen

The Seasonal Ice Zone Observing Network (SIZONet) collects data on local weather conditions, sea ice conditions and sea ice related events, activities, and hazards. Locally identified sea ice experts in six Alaskan communities record their observations daily and send them to collaborating scientists. The data is used to help validate remote sensing data and improve their interpretation, to study ice-shoreline interaction processes and improve their detection in remote sensing data and models, and to improve regional ice and weather forecasts. Users include researchers at the University of Alaska Fairbanks and other academic institutions, the National Weather Service and other research institutions. The partnering communities use the data for education (in particular in schools) and to preserve IK. The SIZONET observing network therefore includes communities, researchers at UAF and NWS, and others (Eicken et al. 2014).

The Bering Sea Sub-Network (BSSN) is a CBM network comprised of eight communities in Alaska and Russia that was initiated by the Aleut International Association (AIA). The program has demonstrated ways of comparing and, when appropriate, aggregating data sets in order to scale information. BSSN collects data on perceptions of change in environmental conditions, including flora and fauna; subsistence harvest locations; unusual observations at harvest locations; challenges to harvesting (ecological & socio-economic, such as lack of resources needed to hunt); observations of the health of the harvested species; observations of new or unusual species; and harvest uses and methods of preservation for harvested foods. These observations are recorded using a standardized mixed method survey developed collaboratively by researchers and community representatives. The survey yields quantitative, qualitative, and spatial data sets that can be compared and aggregated across communities as appropriate (Gofman & Smith 2009).

The Alaska Native Tribal Health Consortium (ANTHC) runs the Local Environmental Observers (LEO) Network as part of its Rural Alaska Monitoring Program (RAMP). The overall goal of RAMP was the creation of village-based environmental monitoring in rural Alaskan villages. Of particular interest is improved understanding of climate-influenced transport of contaminants and movement of zoonotic pathogens. Local environmental observers (LEOs) use instruments, photos, and video to record local observations of extreme and unusual events, which are posted to a web-based public Google Map. LEOs and their posted observations are then connected to topic experts for further consultation, as needed. LEOs are active in over 100 communities in Alaska and Canada. As information is mapped, LEOs utilize the map to view similar observations and concerns occurring in other parts of Alaska and Canada.

Multi-year sea ice bulges in the shorefast ice near Point Barrow, Alaska. Credit: Matthew Druckenmiller

"The status quo has not been successful at delivering fisheries mandate of sustainable and economically viable fisheries. Since First Nations and Inuit have not been included, the underlying assumption [of the Fish-WIKS project] is that we could do things differently."

— Stephanie Boudreau, Dalhousie University

Recommendations: Scaling observations and supporting network-building

❄ Community: Community-to-community exchange is a promising approach to network building from the perspective of local practitioners; there is a need for more funding to support these types of exchange.

❄ Regional: As interest in CBM grows, it will be helpful to identify ways to standardize some aspects of data collection while remaining faithful to CBM's focus on community priorities and uses. One approach may be to secure the commitment of several community programs to incorporate some non-local monitoring goals into their locally initiated programs. Starting with a very simple, practical, concrete approach where a few indicators and methods are agreed upon may work best.

❄ National/pan-Arctic: In order for CBM data to be shared at national and pan-Arctic levels, potentially interested users (for example, government agencies or Arctic Council working groups involved in assessments) need to develop systems that facilitate interoperability, including the ability to communicate with CBM programs to identify and solicit relevant data.

❄ Pan-Arctic: Pan-Arctic workshops or curricula on CBM that could be delivered online would support network and capacity building while limiting travel expenses. However, limited access to the Internet in some parts of the Arctic could make access to network information distribution challenging.

Inform decision-making and natural resource management

CBM can provide an independent source of information for regional, national and local decision-making, complementing long-term scientific monitoring by government agencies. Multiple sources of observation and monitoring can improve decision-making about natural resource management (Johnson et al. 2015). A review of 104 monitoring schemes (conducted separately from this review) suggests that involving local stakeholders in monitoring enhances management responses at local spatial scales, and increases the speed of decision-making to tackle environmental challenges (Danielsen et al. 2010). Projects in the Atlas describe a variety of uses for the monitoring information they provide, including informing individual, household, community, and government decision-making processes. The emphasis can be on providing information for one scale of decision-making or multiple scales simultaneously.

Communities may not always be aware of all relevant decision-making venues for sharing CBM-generated data and information. Assessing this and considering the political implications of different scales of action would strengthen community capacity for policy engagement in the long term. For example, information about contaminant levels in country foods can shape decisions made at the household level (by limiting consumption of a particular species or part of an animal), at the regional level (by issuing health advisories and recommendations), or at the national or international level (by informing policy development to limit industrial emissions of contaminants). The Northern Contaminants Program (NCP) in Canada tries to address the need for information about contaminants across scales of decision-making, and has a long record of facilitating a two-way flow of information that ensures sharing of results with the community (Shearer and Han 2003).

Governance arrangements set a broader context that facilitates or limits the ability of community-initiated programs to inform natural resource management. In North America, land claim agreements and co-management bodies have led to greater use of IK alongside scientific knowledge in natural resource management decision-making. In Europe and Russia, however, there are relatively few examples of decision-making for natural resource management based on co-management or on CBM and IK initiatives (Johnson et al. 2015).

The Silalirijiit program in Clyde River, Nunavut, Canada, provides weather information that individual hunters use on a daily basis to make decisions about when and where to travel on the land. Shari Gearheard, the project leader, says that the stations are "a scientific tool feeding into hunters' knowledge to make decisions about when to go on the land." At a community level, they also provide information needed for services such as search and rescue. Similarly, the data provided by the Sea Ice Monitoring Network's monitoring stations informs decisions about where it is safe to travel on the ice; this information is often shared and discussed among different households with input from expert hunters.

The Sea Ice for Walrus Outlook (SIWO) initiative in Alaska provides weekly reports from April through June with information on sea ice conditions relevant to walrus in the Northern Bering Sea and southern Chukchi Sea regions of Alaska. SIWO uses satellite images and weather predictions obtained on a weekly basis to report on the location and condition of sea ice. Local observers in the communities also send in their observations and pictures of the current season, as well as relating similarities and differences compared to years past. Researchers from NOAA and UAF send their feedback, comments, and observations as well. This information is posted to the project's website and Facebook page. Hunters in Indigenous communities use the information to plan and coordinate scouting and hunting trips.

The Snowchange Sevettijärvi (Näätämö) Oral History Project conducted a land use study in order to develop the first collaborative management initiative in Finland focusing on the river Näätämö, home of the contemporary Skolt Sámi population (Mustonen 2015). The focus of the project is to advance restorative and adaptive practices in the Näätämö river watershed to preserve Atlantic Salmon stocks. At a broader, national policy level, the Fish-WIKS (Fisheries – Western and Indigenous Knowledge Systems) research project, which is active in a number of sites across Canada including Repulse Bay, Nunavut, specifically aims to analyze and understand how IK of fisheries and aquatic ecosystems can and should inform management for sustainability in Canada. The overall goal is to improve fisheries governance and management by understanding how IK can enhance current regimes for decision-making. The research examines three characteristics of knowledge systems: the valuation, ownership and control of knowledge.

The Arctic Borderlands Ecological Knowledge Co-Op documents observations about the ecosystem within the range of the Porcupine Caribou Herd based on IK and local knowledge, including observations of land, plants, animals, weather, ice and snow, and community life. Community monitors, who receive training in interview techniques and reporting, conduct up to 20 structured interviews each year in their own communities using a questionnaire. Survey data is entered into a central database, and annual reports are produced based on interviewers' assessments of and impressions from the surveys they have conducted. Data is used as a source of information to inform the Porcupine Caribou Management Board on caribou range, condition, and other issues (Russell et al. 2013).

The Harvest and Environmental Records Operational System (HEROS) project, the Nunavut Wildlife Management Board's (NWMB) Community-Based Monitoring Network (CBMN), and the Inuvialuit Settlement Region Community-Based Monitoring Program (ISR-CBMP) were all established with a goal of documenting local observations of wildlife for the purpose of informing wildlife management. The current wildlife management framework in Nunavut draws significantly on quantitative analysis of wildlife population numbers to guide decision-making. The tools developed through these programs aim to aggregate the individual observations made by hunters and resource users so that they would be readily available in a format that could be used for decision-making. For example, in the pilot phase of HEROS, the Kugluktuk Hunters and Trappers Organization used community observations of muskox collected through the project to support their request for an expanded hunting quota. In 2012, the NWMB drew on this information, along with other information sources, in their decision to increase harvest numbers. While the HEROS project has not been extended past its pilot phase, the CBMN has a similar goal of informing the NWMB in developing management plans, identifying important harvesting areas, documenting species distribution, movement, and health, and identifying issues that may require further research. Piniakkanik Sumiiffinni Nalunaarsuineq (PISUNA – Opening Doors to Native Knowledge) is an initiative of the Government of Greenland's Ministry of Fisheries, Hunting and Agriculture to improve the use of local and IK in natural resource management decision-making. The initiative is active in four communities in Disko Bay and Uummannaq Fjord; the goal is to increase local capacity to document and manage living resources, to collect data on environmental phenomena, such as wind, weather, and ice conditions, and to link these observations to management responses. Community members decide what will be monitored, collect, process and interpret the data, discuss trends in resources and resource use, and then propose management decisions that are forwarded to the Village Council. For example, community members concerned about an increase in shrimp trawlers and their impact on wolf fish breeding documented the number of trawler lights at night and convinced the municipal government to start a hearing procedure aimed at restricting the size of allowable vessels (Danielsen et al. 2014). A similar initiative, Opening Doors to Native Knowledge of the Indigenous Peoples of the Nenets Autonomous Okrug, builds on Indigenous knowledge to develop a management approach rooted in the culture of the herding, fishing and hunting communities in the Nenets Autonomous Okrug (NAO) in Russia.

Recommendations: Informing decision-making and natural resource management

❄ Community: Communities may not be aware of all relevant decision-making venues for sharing CBM-generated data and information. Project leaders should assess relevant decision-making venues that would benefit from CBM-generated data and share this information with communities to strengthen community capacity for policy engagement in the long term.

❄ Regional/national/pan-Arctic: The ability of CBM to inform decision-making depends on governance arrangements, which vary considerably between regions and Arctic nations. It is important not to overstate the potential influence of community-produced observations in natural resource management decision-making. The identification of barriers, and the collaboration to overcome them, should be part of a longer-term strategy. Research that considers the links between governance arrangements and effectiveness of CBM may help illuminate the potential and limitations of CBM approaches in different regions.

> "With many people, you have to pay them – just like a scientist. We are not asking for a lot; we are asking to get information from elders or people who live on land, you need to make sure you pay them for their time."
>
> — Inuvialuit Settlement Region resident, Cambridge Bay Workshop

- Regional/national/pan-Arctic: For initiatives seeking to influence decision-making beyond the community level, early outreach to and engagement of representatives from regional, national, and international institutions (such as governments or Arctic Council working groups) may facilitate uptake of community-based observations in these venues. These outreach processes should be built into project planning.

Develop data management protocols for CBM and IK

In order to be effective, CBM programs must contend with issues related to data ownership, control, access, and preservation. Among them are the ethical and effective storage, transfer, and archiving of data (Pulsifer et al. 2012). Compliance with established protocols and standards for community engagement in research and for the protection of IK is an important starting point. There is no single standard that applies to all circumpolar regions and communities, and indeed, there is a need to support local and regional guideline development for research involving IK and community-based observing. This point was highlighted in a number of the workshops, including the need for ethics guidelines in Greenland, in the Sámi regions, and in Russia. The Árbediehtu project is an example of an initiative to develop specific methodologies for documenting, preserving, protecting, and storing IK in a specific local context—in this case, for Sámi reindeer-herding communities in Norway.

A major point of frustration for Indigenous communities in relation to research ethics is the still common experience of having researchers come to conduct research and then leave without ever consulting communities about the analysis or sharing the results back (Gearheard and Shirley 2007). Increasing interest on the part of researchers in Arctic communities and IK is straining systems that already struggle with community capacity to proactively manage research relations. Even when data-sharing agreements are created from the outset of projects, it may be difficult to anticipate the diverse uses and requests for access to data that could come along in the future. Some scientific research projects are not structured to enable long-term, ongoing communication between communities and researchers. It is important to agree upon a plan for long-term data storage and use from the beginning of the project.

Data management infrastructures are often designed to enable data from diverse sources and in various formats to be integrated in a standardized way; the design of these infrastructures, however, rarely takes into account the challenge of interoperability across different cultures (Saab 2009), such as those of IK and science. As CBM projects develop systems of collecting, storing, and sharing data, and as interest in CBM grows in the larger Arctic observing community, new protocols are needed that can facilitate transfer and sharing of diverse types of observations. These protocols should facilitate sharing across platforms (interoperability) and between knowledge systems so that they relay IK based observations in the ways that IK holders intend.

A number of programs in the Atlas make use of spatial data, drawing on a range of digital technology platforms being used in project data management protocols. The Local Environmental Observer (LEO) Network uses a public Google Map to publish human and instrument-based observations, photos and video. Linked to their main website, monthly Google Maps locate observations deemed important by Local Environmental Observers. Locations on the map are associated with descriptive text and one or more photos. The Arctic Eider Society uses the Google Maps platform with more advanced customizations. In these cases, projects are taking advantage of the efficiencies provided by using a widely available data and application development platform. For some projects, this approach works well. In other cases, where data are sensitive and/or protected under an ethics protocol, hosting an application on third party infrastructure may be inappropriate (e.g. some data reported under the Árbediehtu and Evenk Community-Based Transdisciplinary Observatory – BRISK projects).

As part of their protocols, other projects have developed customized tools to facilitate access to observations. The Avativut project provides a web site that includes a dynamic database that can be used to generate custom, downloadable data output filtered on criteria such as village name and data type (e.g. Berry uses, Ice category etc.). The LEO Network uses the public platform of a Google Map to store data in a way that can be downloaded by the public. The SIZONet project provides a custom data access tool. After accepting a usage agreement developed by participating communities, users can perform a full text search filtered by observer, community, or date range. Observations are presented using a summary listing with easy to interpret pictographs and the ability to drill down into the details of an observation record. While more resource intensive to develop, these custom applications allow for flexibility in terms of providing access to data and particular user experiences. Additionally, this approach provides control in terms of where data and applications are hosted.

Lastly, the Árbediehtu project provides a good example of the potential need to consider diverse types of data and information in establishing data management protocols. Data collection methods for the project include video recorded interviews, observations of rituals, documenting meetings, use of historic sources, mapping, and documenting the creation of handicrafts and the practice of traditional culinary traditions. Data management protocols associated with the project include making some data widely available over the Internet while sensitive data are maintained privately in a local repository.

It is clear from this review that there is no standard data management protocol that will meet the needs of all projects. However, we do see the emergence of a pattern of ethically aware data management with selective publication.

Recommendations: Managing data

❄ Community/regional: In addition to negotiating data sharing and knowledge management agreements from the outset of a CBM project, researchers should be aware that there may be a need to revisit these agreements when new requests arise that were neither anticipated nor discussed thoroughly in the project design phase.

❄ Regional/National/Pan-Arctic: Indigenous participants in all of the CBM workshops emphasized the need for regionally and locally specific ethics frameworks that take into account the specific needs of IK holders. Supporting projects and processes to develop these frameworks and make them accessible to communities and researchers should be seen as integral to development of a data management infrastructure for CBM.

❄ National/Pan-Arctic: Data management protocols are widely diverse, which may reflect the diversity of programs themselves. This also may reflect a general lack of knowledge about best practices and options for data management. Supporting the expansion of coordinated, service-oriented initiatives such as ELOKA (the Exchange for Local Knowl-

edge and Observations of the Arctic), which offer data management support for community-based initiatives, could be useful in helping to address this.

Sustain CBM Programs

Difficulties in finding long-term funding commitments pose challenges to sustainability for CBM programs. In the wake of the International Polar Year (IPY), when many new research and monitoring projects were initiated, communities found that funding dried up or was directed towards larger research universities (Kautokeino Workshop). A lack of sustained funding is a challenge shared by all long-term monitoring initiatives, but may be particularly challenging for CBM programs. In Canada, for example, most funding available to support community initiatives runs on an annual cycle, often with the potential for renewal but without any guarantee. Funding uncertainty is not only a disincentive for communities to initiate CBM programs, it also may lead community members who get involved with CBM programs to lose interest or move on to other commitments, since there is no guarantee that the program will still be operating from year to year (Cambridge Bay Workshop). Programs can do a lot to increase the likelihood that they can be sustained over time by building on locally available human capacity and financial resources (Danielsen et al. 2014).

Apart from funding concerns, other factors that present sustainability challenges include staff and scientist turnover as well as failure to see improved management as a result of monitoring. Programs may be successful in compiling data but fail to lead to improved government decision-making because governments may be slow to follow up on their own policies on user-involvement in decision-making on natural resources (Nordic Council of Ministers 2015). Likewise, programs may fail to deliver information that residents find useful for meeting local information needs. They may produce relevant information but fail to deliver it in a user-friendly format or to make it accessible on a timely basis. As discussed under "data management" above, many communities are sensitive to the issue of outside researchers failing to share information or data back with the community; this is particularly problematic when community members have shared their knowledge or observations as part of the data collection.

Community members with project management skills will likely have other opportunities that could draw them away from long-term engagement in CBM initiatives. Discussions at all of the workshops suggested that there is often a need to provide compensation in order to sustain the interest and engagement of local residents. However, this view is not universal throughout the Arctic or among CBM practitioners. Many practitioners also emphasized the importance of creating a paid coordinator position to ensure that programs run smoothly and that data is collected in a centralized repository for analysis and use.

While paying community monitors is generally considered to be a requirement for sustained initiatives, there were some caveats expressed. For example, some CBM practitioners point out the need to ensure that those involved in IK documentation initiatives hold significant experience and knowledge as opposed to those less qualified and motivated primarily for monetary compensation (Cambridge Bay Workshop; Kautokeino Workshop). For a few projects, compensation was viewed as a barrier to long-term sustainability because it necessitated renewed funding from outside sources. Often, citizen science initiatives rely on volunteers to engage in limited data collection. Compensation is rarely provided in these arrangements.

From a broader perspective, CBM programs can only be sustained over the long term when they are applicable to community interests and are meeting community-level needs for information. The ongoing, central involvement of community members in CBM programs is therefore one of the most critical factors to focus on at the program level. This is particularly true because, unlike funding, this is an element of sustainability that can be addressed through program design and ongoing communication and relationship building.

Recommendations: Sustaining CBM programs

- Community: A central component to sustaining CBM programs is to ensure that they address the needs and priorities of community members. To support sustained involvement of key individuals, programs should create a paid coordinator role and ensure that community members are adequately compensated for their time and effort. To make participation easier and more attractive, it could be helpful to build programs around activities that community members are already doing on a regular basis, such as hunting trips.
- Regional/national: Collaborating scientists should share data and information with communities on a timely basis, which will help address concerns about the utility of CBM programs for addressing community information needs.
- National: The current funding infrastructure does not support the long-term nature of monitoring programs. There is a need for long-term funding commitments for CBM initiatives to ensure that programs can build sustainable practices and can gather data over time; this will enhance the value of the data to decision-makers.

Opposite page: Jukajoki River flows near the villages of Selkie and Alavi, Finland. Credit: Chris McNeave

Next Steps

This review of CBM programs was conducted as part of a SAON task to consider how to support the further development and utilization of observing based on CBM and IK. The recommendations above highlight ways that Arctic community members, practitioners, funders, and the larger observing community can build on strengths and address challenges. As a network of observing networks, SAON has a role to play in facilitating engagement of CBM in Arctic observing and monitoring. We see a particular role for SAON in the following areas:

1. *Supporting identification of best practices and standards for community involvement.* This review represents an initial step in examining different approaches to CBM from a circumpolar perspective. The scope of this process was limited, however, and many of the conclusions and findings are based on the interpretation of a relatively small group of authors. There is a need for a broadly inclusive, bottom-up process to identify best practices for community-based monitoring, including standards for community leadership and involvement. Because of differences in approach and varying governance arrangements in different parts of the Arctic, this may be more effective as a series of regional efforts accompanied by strong communication between regions. SAON can play a role in supporting these efforts by recognizing their importance to advancing CBM and by disseminating results within the international Arctic observing community.

2. *Promoting data and methods standardization.* Although support for CBM should enable diverse approaches to data collection depending on the specific goals of the community, SAON can play a role in promoting greater standardiza-

A diver sees this view of the underside of the ice. Alaska, Beaufort Sea, North of Point Barrow. Credit: Elisabeth Calvert

tion and coordination of methods for data collection that is culturally appropriate and supports the knowledge system/s from which the data are derived. This may be particularly relevant for those programs that wish to make data available for assessment processes and decision-making at regional and pan-Arctic levels. While data standardization is an important overall goal to facilitate data sharing and use, care must be taken to allow for overall flexibility that can support involvement of diverse methodologies and knowledge sources and nurture the knowledge systems from which the data is derived.

3. Disseminating ethics frameworks for CBM and observing programs based on IK. As discussed in this review, ethical approaches to documenting observations require that all parties involved discuss and agree on protocols for data collection, documentation, ownership, control, access, possession, dissemination, and long-term storage and use. SAON can help raise awareness about ethical issues related to documentation of IK and can promote adoption of ethics frameworks by the observing networks that participate in SAON.

4. Supporting the development of platforms that facilitate connection and network building among CBM initiatives. The Atlas of Community-Based Monitoring in a Changing Arctic is one such platform that will require additional investment to stay up-to-date and to build new services that will facilitate information sharing and network building. Other platforms that can facilitate connection include ArcticHub (www.arctichub.net) as well as regional platforms such as the US Interagency Arctic Research Policy Committee (IARPC) collaborations site (www.iarpccollaborations.org). Each of these platforms has a different intended audience but could be used as a tool to facilitate linkages. SAON can help facilitate connections between platforms (which will also help avoid duplication) and raise awareness about www.arcticcbm.org as a platform dedicated solely to CBM.

5. Ensuring involvement of CBM practitioner perspectives in SAON working groups and processes. While CBM is recognized as an important component of Arctic observing, participation by individuals with significant knowledge of CBM has been limited. Recognizing that SAON is largely a voluntary effort without dedicated funding, it may be possible to work towards the establishment of funding mechanisms and to seek external support to ensure that CBM practitioners are able to participate directly in SAON processes and working groups.

Opposite page: Siorapaluk, Greenland is the most northerly community in the world. Credit: Andy Mahoney

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Appendix 1: List of Projects

Title	Lead Organization	Country Headquarters	IK Involvement	Start Year
Alaskan Inuit Food Security Conceptual Framework: How to Assess the Arctic From an Inuit Perspective	Inuit Circumpolar Council-Alaska	USA	Y	2012
Ájddo—reflections about biodiversity in reindeer tracks	Swedish Sami Parliament	Sweden	Y	2011
Árbediehtu	Sámi University College	Norway	Y	2008
Arctic Fox Monitoring	The Arctic Fox Centre	Iceland	N	1998
Avativut: Bridging Environmental Science and Community-based monitoring through Inuit School curriculum	Université du Québec à Trois-Rivières (UQTR) and Institut national de la recherche scientifique (INRS)	Canada	Y	
Bering Sea Sub-Network (BSSN): A Distributed Human Sensor Array to Detect Arctic Environmental Change	Aleut International Association (AIA); University of Alaska Anchorage	USA	Y	2007
Birgen: Traditional Knowledge and Education in Reindeer Husbandry	International Centre for Reindeer Husbandry	Norway	Y	2008
Bowhead Coastal Observation Project	Association of Traditional Marine Mammal Hunters of Chukotka (ATMMHC)	Russia	Y	1992
Cambridge Bay Observatory	Ocean Networks Canada	Canada	N	2012
CEAVVI	Uarctic EALÁT Institute at International Centre for Reindeer Husbandry	Norway	Y	2007
COASST	University of Washington	USA	N	1998
Community Ecological Monitoring Program	Government of Yukon, Canada	Canada	N	2003
Community-Based Monitoring Network (CBMN)	Nunavut Wildlife Management Board	Canada	Y	2012
Development and Implementation of a Community-Based Fishery Monitoring Programme and Stock Assessment Framework for Arctic Char in Baffin Region, Nunavut	Fisheries and Oceans Canada	Canada	Y	
Discover Alaska's Whales	Gastineau Guiding Company	USA	N	2009
Documenting Traditional Knowledge of Migratory Behavior of Western Arctic Herd Caribou	National Park Service	USA	Y	2012
EALÁT	Sámi University College	Norway	Y	2006

Title	Lead Organization	Country Headquarters	IK Involvement	Start Year
Ecomapping in Kustringen	Kustringen	Sweden	N but LK	2006
ECORA - An Integrated Ecosystem Management Approach to Conserve Biodiversity and Minimise Habitat Fragmentation in Three Selected Model Areas in the Russian Arctic	UNEP / GRID-A	Russia	Y	1999
Ecosystem monitoring in Kugluktuk	Université de Moncton	Canada	Y	2014
Fávllis—Sámi Fishery Research Network: Local ecological knowledge on fjords	Centre for Sámi Studies, University of Tromso	Norway	Y	2003
Fish-WIKS (Fisheries, Western and Indigenous Knowledge Systems)	Dalhousie University	Canada	Y	2012
Fuglavernd Winter Garden Bird Survey	Fuglavernd	Iceland	N	1994
Grazing of outlying land—a biological cultural heritage as resource for a sustainable future	Swedish Biodiversity Centre, Swedish University of Agricultural Sciences	Sweden	Y	2011
Guardians of the Walrus Haulouts (Haulout Keepers)	The Association of Traditional Marine Mammal hunters of Chukotka (ATMMHC)	Russia	Y	2009
Harvest and Environmental Records Operational System (HEROS)	Government of Nunavut, Department of Environment	Canada	Y (primarily LK)	2011
Hunter moose monitoring in Sweden	Swedish University of Agricultural Sciences	Sweden	N	
Igliiniit Project	Ittaq with Carleton University and University of Calgary	Canada	Y	2006
Improvement of the animals' nutrition, health, and well-being through nutritionally adapted management actions in reindeer herding	Swedish University of Agricultural Sciences	Sweden	Y	2007
Indigenous monitoring and education on climate change: from grassroots measures to state adaptation plan	Centre for Support of Indigenous Peoples of the North	Russia	Y	2010
Indigenous Rights and Nature Conservation in Fennoscandinavia	Luleå University of Technology	Sweden	Y	2010
Kachemak Bay Shorebird Monitoring Project	Kachemak Bay Birders	USA	N	2008
Kangiqtugaapik (Clyde River) Weather Station Network (Silalirijiit Project)	Ittaq Heritage and Research Centre in collaboration with the University of Colorado and Colorado State University	Canada	Y	2009
KBRR Harmful Algal Bloom Program	Kachemak Bay Research Reserve	USA	N	2008
KBRR Invasive European Green Crab Program	Kachemak Bay Research Reserve	USA	N	2006
KBRR Invasive Tunicate Watch Program	Kachemak Bay Research Reserve	USA	N	2004
KBRR Shellfish Monitoring Program	Kachemak Bay Research Reserve	USA	N	2012
Kugluktuk Berry Monitoring Project	University of British Columbia	Canada	Y	2009
Local Environmental Observer (LEO) Network	Alaska Native Tribal Health Consortium	USA	Y	
Long term use in Sápmi—traditional knowledge and mapping of cultural heritage	Norwegian Institute for Cultural Heritage Research	Norway	Y	2009

Title	Lead Organization	Country Headquarters	IK Involvement	Start Year
Mapping of macrofungi in Norway	Norwegian Mycological- and Ethnobotanical Society	Norway	N	1995
Marked Species	Institute of Marine Research (IMR)	Norway	N	2006
Melibee Project	University of Alaska Fairbanks	USA	Y	2012
Monitoring of Development of Traditional Indigenous Land Use Areas in the Nenets Autonomous Okrug	Association of Nenets People 'Yasavey'	Russia	Y	2007
Nomadic Herders	World Reindeer Herders' Association (WRH)	Norway	Y	2014
Opening Doors to the Native Knowledge of the Indigenous Peoples of the Nenets Autonomous Okrug	Yasavey Association of Nenets People	Russia	Y	2012
Organic nutrients and contaminants in subsistence species	Kotzebue IRA	USA	Y	2004
PISUNA	Ministry of Fisheries, Hunting and Agriculture, Government of Greenland	Greenland	Y	2010
PITE – from coast to coast	Tromsø University	Norway & Sweden	Y	2011
Planning for impact assessments of the establishment of large-scale wind farms—effects on reindeer	Swedish Environmental Protection Agency	Sweden	N	2008
Renbruksplan (Reindeer husbandry plan)	Swedish Forest Agency	Sweden	Y	2000
Sea Ice for Walrus Outlook (SIWO)	Arctic Research Consortium of the US (ARCUS)	USA	Y	2010
Sea Ice Monitoring Network	Ittaq Heritage and Research Centre and University of Colorado Boulder	Canada	Y	
SIZONet Community Sea Ice Observing Network	Geophysical Institute, University of Alaska Fairbanks	USA	Y	2006
Snowchange Deatnu Oral History Project	Snowchange Cooperative	Finland	Y	2001
Snowchange Jokkmokk Oral History Project	Snowchange Cooperative	Finland	Y	2002
Snowchange Murmansk Oral History Project	Snowchange Cooperative	Finland	Y	2001
Snowchange Ponoi Oral History Project	Snowchange Cooperative	Finland	Y	2009
Snowchange Sevettijärvi (Näätämö) Oral History Project	Snowchange Cooperative	Finland	Y	2009
Snowchange Vuotso Oral History Project	Snowchange Cooperative	Finland	Y	2001
Southeast Alaska Long-term Monitoring (SALMoN) Program	Sitka Conservation Society	USA	N	2012
Spring migration phenology of birds	Tromsø University Museum	Norway	N	1975
Supporting democratic participation of northern Indigenous Peoples in the Russian Federation	Centre for Support of Indigenous Peoples of the North	Russia	Y	2011
The Evenk Community-Based Transdisciplinary Observatory (BRISK)	University of Versailles Saint Quetin-en-Yvelines	France	Y	2013
The Great Seal Count	The Icelandic Seal Center	Iceland	N	2007

Title	Lead Organization	Country Headquarters	IK Involvement	Start Year
The Wild North—whale watching	The University of Iceland	Iceland	N	2008
TOV-E—extensive surveillance of birds	Birdlife Norway (NOF)	Norway	N	2005
Traditional knowledge of Chukotka native peoples regarding polar bear habitat use	The Association of Traditional Marine Mammal hunters of Chukotka (ATMMHC)	Russia	Y	2009
Traditional Knowledge of the Native People of Chukotka About Walrus (part of the Bilateral Walrus Monitoring project)	The Association of Traditional Marine Mammal hunters of Chukotka (ATMMHC)	Russia	Y	2009
Transferring and using Traditional Ecological Knowledge among Sámi Reindeer Herding Women	Ájtte, Svenskt Fjäll-och Samemuseum, Jokkmokk, Sweden	Sweden & Norway	Y	2011
Trilateral cooperation on our common resource; the Atlantic salmon in the Barents region	The County Governor of Finnmark	Norway, Finland, Russia	N (LK in-volved)	2011
Udtja, various projects related to brown bear and reindeer calf predation in Udtja and Gällivare skogssamebyer	Udtja and Gällivare skogssameby	Sweden	Y	2010
Using Traditional Ecological Knowledge to observe if Climate Change has an effect on Reindeer and Reindeer Husbandry	Ájtte, Swedish Mountain and Sámi Museum	Sweden	Y	2010
Western Hudson Bay Polar Bears and Public Opinion	Nunavut Wildlife Management Board	Canada	Y	2012
Wildlife triangles Finland	Finnish Game and Fisheries Research Institute	Finland	N	1988
Willow Creek Research Project	Willow Creek Water Consortium	USA	Y	2009
	Protect Sapmi	Norway	Y	2012
	Arctic Eider Society	Canada	Y	
	Alaska Community Action on Toxins (ACAT)	USA	Y	1997
	Eskimo Walrus Commission	USA	Y	1978
	Arctic Borderlands Cooperative	Canada	Y	1996

Appendix II: Questionnaire

Atlas of Community-based Monitoring in a Changing Arctic
Questions for CBM Programs/Initiatives

We are pleased to have your community-based monitoring or traditional knowledge initiative join the Atlas of Community-Based Monitoring (CBM) in a Changing Arctic! Please fill out this form and email it to arcticcbm@inuitcircumpolar.com. You should receive a confirmation email within two business days of sending in the form; if you do not, please feel free to contact us again. You can also withdraw your project from the Atlas at any time by contacting us using this address or any of the other email addresses in the "contact" link at www.arcticcbm.org.

The information you provide in this form will be made publicly available on the Atlas website at www.arcticcbm.org. We will also use the information for a report on the state of community-based monitoring in the Arctic, and it may be used in aggregate in publications or presentations related to this project.

Please answer the following:

1. Project or program title:

2. Organization name:

3. Contact name(s):

4. Address, phone, email (please include all three):

5. Funders:

6. Project start date (day, month and year – if day or month unknown, year is fine):

7. Project end date, if applicable:

8. Project progress (to check a box, click on it twice. In the pop-up box, click on "checked" in the right corner under "default value," then click "okay"):

☐ Planned
☐ In progress
☐ Complete
☐ Ongoing
☐ Temporarily on hold pending funding

9. Project website (if applicable):

10. URL where data can be accessed (if applicable):

11. Do you contribute data to any of the following data catalogues:

☐ Polar Data Catalogue
☐ ACADIS
☐ Other:

12. Location(s) of project (if multiple locations, list on separate lines below or give website address where project locations can be found):

13. What are you monitoring? (check all that apply):

☐ Terrestrial animals
☐ Fish/Marine mammals
☐ Birds
☐ Plants, flora
☐ Human health
☐ Food security
☐ Lakes/rivers/streams
☐ Glaciers and/or snow
☐ Sea ice
☐ Weather
☐ Air quality
☐ Permafrost & terrestrial issues
☐ Resource extraction, industry & development
☐ Tourism
☐ Land/sea use
☐ Social/cultural/economic issues (specify under "other")
☐ Governance & rights
☐ Other (please specify):

14. What overarching issues is your monitoring project concerned about? (Check all that apply):

☐ Biodiversity
☐ Contaminants
☐ Climate change
☐ Resource extraction, industry & development
☐ Continuity and transmission of traditional knowledge
☐ Human health, wellness, and well-being

- ☐ Animal/fish/marine mammal health, wellness, and well-being
- ☐ Food security
- ☐ Social/cultural/economic issues (please specify below)
- ☐ Governance & rights
- ☐ Other (please specify):

15. Project conceived or initiated by:

- ☐ Community
- ☐ Government agency
- ☐ Researcher
- ☐ Non-governmental organization
- ☐ Indigenous organization
- ☐ Other:

16. What are the primary goals/aims of the initiative?

17. Which of the following best describes the intended functions of the initiative?

- ☐ Research (finite data collection)
- ☐ Monitoring (ongoing collection)
- ☐ Education/advocacy
- ☐ Application of data to decision-making
- ☐ Network building
- ☐ Service delivery
- ☐ Other:

18. How is data collected, shared, and stored?

19. How is data used? Can you give examples of decisions that have been made based on the data collected?

20. What components of the project/initiative involved community members?

- ☐ Project design
- ☐ Data collection
- ☐ Data interpretation/analysis
- ☐ Communication of information & results
- ☐ Application of data/decision-making based on data
- ☐ Other – Please specify:

21. Does this project involve traditional knowledge?

- ☐ Yes
- ☐ No

22. (If yes): How is traditional knowledge involved in your initiative and at what stages (design, data collection, data analysis)?

23. Do you collaborate with other researchers, communities, or government employees? If so, who? Please describe the different roles they have in the project.

24. Do you or your collaborators have publications associated with this project? If so, please include a web address or publication information:

25. Are you willing to participate in a short follow-up interview by phone? These interviews will inform the development of a comprehensive report on the state of CBM in the Arctic.

- ☐ Yes
- ☐ No

26. Do you have a photo of your project that you would be willing to share on the website?

- ☐ Yes (please include as an attachment)
- ☐ No

(If yes) Photo credit/name of photographer:

(If yes) If you would like to include a caption, please include text here as you would like it to read on the website:

27. Are there other projects you are aware of that you think should be part of this Atlas?

Thank you for your participation in the Atlas! We'll be in touch to let you know when your project is ready to view online.

Appendix III: Summary of Recommendations

	Community	Regional	National	Pan-Arctic
Building capacity				
During program design, project leaders should consider the potential impact on local and Indigenous institutions. Does the program include funding to hire and train local staff in various roles, both for data collection and interpretation as well as for program administration and management?	✓			
Capacity building goes both ways: it is important to build the capacity of scientists to work with communities and not only the other way around. Including a skill mapping exercise in the planning phase can help identify opportunities to share and transfer skills among collaborators.	✓		✓	
Permanent Participant (PP) organizations of the Arctic Council are already involved in representing CBM within SAON and Arctic Council working groups, but capacity and resources limit their involvement. Increasing involvement of PPs and IK holders involved with monitoring programs will enhance Pan-Arctic discussions on observing and monitoring. Additionally, further linkages between sub-national, national and regional level representative structures will facilitate greater exchange of information about relevant new and ongoing monitoring initiatives.				✓
Engaging IK and co-producing observations				
Project leaders should ensure that community members, including IK holders when relevant, are centrally involved in setting goals for CBM programs based on co-production; consider how different types of observations, including those based on both IK and scientific measurement, could contribute to meeting these goals.	✓			
Sound relationships for knowledge co-production are built over time and usually involve knowledge exchanges that are both personal and professional. Rather than simply organizing workshops for formal exchange, hands-on activities to build relationships could be considered. This could include travelling together on the land as well as hosting northern community members at the institutional homes of collaborating scientists.	✓			
Co-production may be particularly relevant for regional observing and monitoring initiatives that require diverse sources of information to meet multiple user needs. In regionally designed programs, the specific interests of each community involved should be considered, keeping in mind that interest, relevance, and availability of TK to monitoring and observing may vary between communities, even in the same region.		✓		
Arctic residents should be recognized for their ability to engage in monitoring on an ongoing basis as initiators of and/or contributors to CBM programs. Their observations, including those by TK holders, should be recognized as an important source of observing information in national observing and monitoring plans and in Arctic Council working group initiatives, including CAFF's Circumpolar Biodiversity Monitoring Programme and the Sustaining Arctic Observing Networks activities.			✓	✓

	Community	Regional	National	Pan-Arctic
Engaging diversity				
There is a need for more attention to women's observations and knowledge in CBM programs. Programs should consider how women's knowledge can be utilized in monitoring and observing.	✓			
While some programs incorporate youth training as part of CBM and TK initiatives, overall, this is an under-developed aspect of community participation in observing and monitoring. Programs should consider how they can incorporate youth engagement.	✓			
Regional authorities should consider how programs can be linked or expanded to other communities in order to capture diversity and provide opportunities for capacity building and knowledge mobilization and transfer.		✓		
Funding programs for CBM activities could create special categories or incentives for participation by social groups that are traditionally under-represented in CBM activities, including women and youth.			✓	
Adapting technologies				
Programs should consider plans for long-term data ownership, processing and transfer in project design. Information about wildlife harvesting can be sensitive, and data processing requires specialized knowledge and equipment. Programs that use information and communication technologies (ICTs) to geolocate harvest related information should negotiate long-term data ownership and management from the outset and should prioritize protection of sensitive information.	✓			
To defray the high costs of ICTs, including the need for upkeep and maintenance, programs could consider involving third party technology developers and managers; this would distribute costs across multiple users and programs and help transfer or share technologies. Another option worth considering is whether similar technological approaches have been developed for other projects that could be adapted through collaboration and network building. Hosting, interoperability, and standardization are all issues that need to be considered when exploring various options.		✓	✓	
Scaling observations and supporting network-building				
Community-to-community exchange is a promising approach to network building from the perspective of local practitioners; there is a need for more funding to support these types of exchange.	✓			
As interest in CBM grows, it will be helpful to identify ways to standardize some aspects of data collection while remaining faithful to CBM's focus on community priorities and uses. One approach may be to secure the commitment of several community programs to incorporate some non-local monitoring goals into their locally initiated programs. Starting with a very simple, practical, concrete approach where a few indicators and methods are agreed upon may work best.		✓	✓	
In order for CBM data to be shared at national and pan-Arctic levels, potentially interested users (for example, government agencies or Arctic Council working groups involved in assessments) need to develop systems that facilitate interoperability, including the ability to communicate with CBM programs to identify and solicit relevant data.			✓	✓
Pan-Arctic workshops or curricula on CBM that could be delivered online would support network and capacity building while limiting travel expenses. However, limited access to the Internet in some parts of the Arctic could make access to network information distribution challenging.				✓

	Community	Regional	National	Pan-Arctic
Informing decision-making and natural resource management				
Communities may not be aware of all relevant decision-making venues for sharing CBM-generated data and information. Project leaders should assess relevant decision-making venues that would benefit from CBM-generated data and share this information with communities to strengthen community capacity for policy engagement in the long term.	✓			
The ability of CBM to inform decision-making depends on governance arrangements, which vary considerably between regions and Arctic nations. It is important not to overstate the potential influence of community-produced observations in natural resource management decision-making. The identification of barriers, and the collaboration to overcome them, should be part of a longer-term strategy. Research that considers the links between governance arrangements and effectiveness of CBM may help illuminate the potential and limitations of CBM approaches in different regions.		✓	✓	✓
For initiatives seeking to influence decision-making beyond the community level, early outreach to and engagement of representatives from regional, national, and international institutions (such as governments or Arctic Council working groups) may facilitate uptake of community-based observations in these venues. These outreach processes should be built into project planning.		✓	✓	✓
Managing data				
In addition to negotiating data sharing and knowledge management agreements from the outset of a CBM project, researchers should be aware that there may be a need to revisit these agreements when new requests arise that were neither anticipated nor discussed thoroughly in the project design phase.	✓	✓		
Indigenous participants in all of the CBM workshops emphasized the need for regionally and locally specific ethics frameworks that take into account the specific needs of IK holders. Supporting projects and processes to develop these frameworks and make them accessible to communities and researchers should be seen as integral to development of a data management infrastructure for CBM.		✓	✓	✓
Data management protocols are widely diverse, which may reflect the diversity of programs themselves. This also may reflect a general lack of knowledge about best practices and options for data management. Supporting the expansion of coordinated, service-oriented initiatives such as ELOKA (the Exchange for Local Knowledge and Observations of the Arctic), which offer data management support for community-based initiatives, could be useful in helping to address this.			✓	✓
Sustaining CBM programs				
Central to sustaining CBM programs is ensuring that they address the needs and priorities of community members. To support sustained involvement of key individuals, programs should create a paid coordinator role and ensure that community members are adequately compensated for their time and effort. To make participation easier and more attractive, it could be helpful to build programs around activities that community members are already doing on a regular basis, such as hunting trips.	✓			
Collaborating scientists should share data and information with communities on a timely basis, which will help address concerns about the utility of CBM programs for addressing community information needs.		✓	✓	
The current funding infrastructure does not support the long-term nature of monitoring programs. There is a need for long-term funding commitments for CBM initiatives to ensure that programs can build sustainable practices and can gather data over time; this will enhance the value of the data to decision-makers.			✓	