Strengthening community-based monitoring in the Arctic: Key challenges and opportunities

A Community White Paper
Prepared for the Arctic Observing Summit 2013

Authors:

Noor Johnson,* Brown University, in collaboration with the Inuit Circumpolar Council-Canada
Lilian Alessa, The Resilience and Adaptive Management Group, University of Alaska
Shari Gearheard, National Snow and Ice Data Center, CU-Boulder
Victoria Gofman, Collaborative Research and Consulting
Andrew Kliskey, The Resilience and Adaptive Management Group, University of Alaska
Peter Pulsifer, Exchange for Local Observations and Knowledge of the Arctic, CU-Boulder
Michael Svoboda, Circumpolar Biodiversity Monitoring Program

* Corresponding author: Noor_Johnson@Brown.edu

Executive Summary

Community-based monitoring (CBM) engages Arctic residents, including traditional knowledge holders, in ongoing observing and monitoring of Arctic change. While CBM offers fine-grained local scale data that is readily accessible to local scale decision-makers, it has not yet reached its potential. CBM initiatives are not well documented or networked, with the result that practitioners and supporters lack a clear sense of the field and how to best support its growth and development.

In this paper, we consider how improvements might be made to the design, implementation, and coordination of community-based monitoring and observing systems in the Arctic. We focus on emerging standards and highlight challenges as they relate to several critical themes, including: community engagement, tools and methods, data management, sharing, application and use of information, and sustainability and capacity building. We conclude that community-based monitoring has the potential to make significant contributions towards the development of a robust international Arctic observing system. The field, however, is at a critical juncture and requires sustained investment and committed engagement from the Arctic observing community.

Introduction and definitions

Community-based monitoring (CBM) engages the capacities of Arctic residents in ongoing observing and monitoring of Arctic change. CBM has been defined as "a process where concerned citizens, government agencies, industry, academia, community groups and local institutions collaborate to monitor, track, and respond to issues of common community concern" (Ecological Monitoring and Assessment Network 2003). Monitoring of the Arctic did not begin with the introduction of formal Western scientific monitoring initiatives; Arctic Indigenous peoples have been systematically observing the environment for millennia. Contemporary approaches to CBM often incorporate traditional or Indigenous knowledge, sometimes along with Western scientific methods to co-produce knowledge.

Traditional knowledge (TK) refers to the cumulative and transmitted knowledge, experience, and wisdom of human communities with a long-term attachment to place (Kliskey et al. 2009). TK is sometimes referred to as Indigenous knowledge (IK) to emphasize the knowledge that has been acquired and transmitted over thousands of years by people with a sustained and direct connection with the land and sea. Some researchers and Indigenous practitioners prefer the term "Indigenous science" because it emphasizes the dynamic nature of these knowledge systems, the systematic nature of observations they generate, and the fact that science is not a uniquely Western paradigm (Alessa et al. 2012). In contrast, **local knowledge** (LK) refers to the knowledge of the local residents of a community, often the users of local resources, primarily involves knowledge of local species and dynamics, and is not necessarily embedded within an explicit belief system (Kliskey et al. 2009). In this paper, we use the term "traditional knowledge" because we believe it is a term that many readers will be familiar with, however we recognize that issues of terminology are ongoing and would benefit from further discussion and resolution.

Formal monitoring projects that define themselves as "**community-based**" use different approaches to community engagement. At one end of the spectrum, government or academic researchers may enlist community members in collecting data for projects driven by the information needs of institutions located outside the community. At the other end, community members and community institutions drive the establishment of the monitoring initiative based on information needs within the community. Within this range, community members may be involved in some or all aspects of the project, from setting goals and defining methods, to data collection and interpretation, to sharing the data produced (Danielsen et al., 2009, Gofman 2010). There is further work to be done to more towards a more standardized definition of community-based monitoring based on best practices in the Arctic; some initial observations about successful approaches are detailed in the section on "community engagement" below.

While **research** is usually hypothesis based and therefore involves investigation of a phenomena or issue over a finite period of time, **monitoring** is sustained and ongoing, although as we discuss in the "sustainability" section below, there are a number of barriers to sustainability for formal monitoring initiatives. While monitoring is not primarily hypothesis based, it offers important data that informs formal research programs. Within communities, informal monitoring and observing plays a significant role in daily life, providing information that is critical to safe travel and successful hunting and harvesting activities. Formal monitoring also has an important role to play in supporting decision-making within communities and at the regional level.

As an approach to Arctic Observing, CBM has many advantages. In the vast northern regions, difficult access and the high cost of infrastructure make gathering data year-round a challenge for scientists. Local residents, especially in Indigenous communities, possess intimate knowledge about the environment, have genuine interest in sustaining biological resources vital for their survival and food security, and are capable of acquiring skills to participate in organized and systematic data gathering.

In spite of these advantages, CBM has not yet reached its full potential; it is under-recognized and poorly understood within wider Arctic monitoring networks. There are several reasons for this. Because the scientific and funding networks that support Arctic monitoring are historically grounded in Western science approaches, community-led CBM projects that integrate traditional knowledge are at a relative disadvantage in terms of access to funding and recognition. Even when communities secure funding, sustaining these commitments to ongoing monitoring remains a challenge. Additionally, the results of community-based projects, whether focused on traditional knowledge or co-production of knowledge using scientific and traditional knowledge, are not always shared widely beyond the community level. This limited distribution contributes towards the continued lack of familiarity of CBM and TK applications.

Finally, there remains a bias in the Western science community against traditional knowledge and against monitoring done by community residents who lack Western scientific training. In some cases, monitoring based on traditional knowledge may be invisible to researchers from outside the community, who do not understand the local context or the reasons why community members prioritize certain phenomena for monitoring over others. As a result of these different factors, the full range of community-based monitoring and traditional knowledge projects that exist across the Arctic are not well documented or understood.

In this white paper, we consider how improvements might be made to the design, implementation, coordination, and sustained long-term operation of community-based monitoring and observing systems in the Arctic. We focus on emerging standards and gaps in implementation as they relate to several themes: community engagement, tools and methods, data management, sharing, application and use of information, and sustainability and capacity building.

I. Community engagement and the utilization of community-based approaches

Involvement of community residents is a defining characteristic of community-based monitoring. Arctic residents have a wealth of knowledge about their lands, waters, and territories, and are interested in contributing to research efforts that will draw on their knowledge as well as Western science to address issues of importance. Since Arctic communities are regionally and internally diverse, the term “community-based” does not imply that the entire community is equally involved or invested in monitoring, but rather that the project engages the expertise and ongoing involvement of some residents. These may be traditional knowledge holders who are recognized as experts within the community, as well as individuals interested in learning scientific methods and adapting technologies to meet local needs.

While the indicators used by Western scientists and Arctic Indigenous peoples to monitor the environment sometimes overlap, Indigenous peoples have their own ways of monitoring and their own preferred indicators based on sustained engagement and interaction with the environment over time. Their attentiveness to and understanding of alternate indicators can provide novel approaches to monitoring that may yield significant insights about the nature of environmental change. For example, Inuit have observed that the weather during the spring months is more changeable than in the past. Drawing on this observation, meteorologists analyzed weather persistence, the “tendency of a warmer than normal day to be followed by another warmer than normal day” (Weatherhead et al. 2010:525). They found that over the past 20 years, weather persistence in the spring has dropped, a finding that matched Inuit observations (Weatherhead et al. 2010). The Western science researchers involved noted that it was Inuit knowledge that supplied an insight that prompted them to focus on weather persistence, and emphasized that combining Indigenous knowledge and Western science can lead to novel insights.

A collaborative approach to CBM involves both scientific researchers and residents, including traditional knowledge holders (Getz et al. 1999; Danielsen et al. 2009; Conrad and Hilchey 2011); this has been referred to as “knowledge co-production” (Armitage, Berkes et al. 2011; Kofinas 2002; UNESCO 2012). As Brook and colleagues have suggested, “CBM may be most effective at engaging communities and scientists and provide the most relevant and useful information if it facilitates the inclusion of both local knowledge and scientific data in a way that identifies the benefits and limitations of each” (Brook et al. 2009:267). By using this approach, a number of collaborative projects have documented Arctic community members’ detailed knowledge of key components of their environment, such as sea-ice (Laidler 2006; Mahoney et al. 2009), weather patterns (Gearheard et al. 2010; Weatherhead et al. 2010) and caribou (Ferguson et al. 1998, Russell et al. 2013).

Studies of CBM projects have pointed toward approaches to engagement that guide successful, sustained initiatives. Researchers seeking to establish monitoring programs with communities are most successful when they have a strong understanding of ethics protocols and practices for working with Indigenous knowledge holders, including intellectual property rights and data stewardship rights and responsibilities (see “data management” below), and take an open and engaged approach to communication with community members (Gearheard & Shirley, 2007).

Anecdotal evidence suggests that robust community engagement is a key factor in the sustainability of CBM projects and initiatives. A number of factors impede engagement, including turnover of research assistants and staff members of local institutions, under-resourcing the project so that community participants are not adequately compensated for their contributions, among others (see "sustainability and capacity building" below). These have implications for the temporal duration of projects and whether or not observations are sustained over time. Collaborative projects are likely to be more successful if they are context specific, flexible, and adaptive (Pollock & Whitelaw, 2005), and if they take into consideration local needs, benefits, motivation, and capacity to engage in formal monitoring partnerships. One strategy that has been successful is to incorporate monitoring activities into the existing everyday activities of local residents.

In some cases, communities may be interested in soliciting outside expertise to develop a monitoring program, or Western-trained scientists may be eager to partner with communities, but both may be unsure of how to initiate collaborative projects. Investing in local institutions and initiatives that can help liaise between outside researchers and community members may help overcome some of these issues. For example, the Ittaq Heritage and Research Centre in Clyde River, Nunavut, was established to support community leadership in research (www.ittaq.ca). At the regional level in Canada, Inuit Research Advisor positions have been established to help advise communities and outside researchers on approaches to collaborative research and address concerns that might arise. Another example is the Alaska Native Science Commission (www.nativescience.org), which supports collaborations between Native communities and researchers, serving as a clearing house and archive for past and ongoing research. Further research on the factors that shape successful partnerships between communities and scientists, as well as challenges that can cause partnerships to break down, might yield insights that could improve collaboration in future projects.

It is also important to keep in mind that communities around the Arctic are engaged in informal monitoring and observing based on traditional knowledge and ongoing environmental engagement. Efforts to more comprehensively document these local observing traditions and systems, including how monitoring information is shared among residents of a community, would help ensure that newly established CBM projects build on rather than compete with these ongoing local observing networks.

It is also true that term "community-based monitoring" has more regional recognition in Alaska and Canada, for example, than it does in other regions. An important initial step is therefore to document the many CBM and traditional knowledge projects that have been completed or are underway across the Arctic, and to then analyze and compare the different approaches used. Several projects are underway that will help address this gap. These include the Circumpolar Biodiversity Monitoring Program's Indigenous Knowledge Inventory and the Atlas of Community-Based Monitoring in a Changing Arctic, which will be part systematic review of circumpolar community-based monitoring projects being prepared in conjunction with SAON. Because CBM projects are implemented and often initiated at the local scale, however, the work of documenting and network building among initiatives will be ongoing and will require investment of resources (see "sustainability" below).

What's needed to improve community engagement and the utilization of community-based approaches to monitoring:

- Increased awareness of significance and value of TK on the part of Western-trained scientists;

- Research on successful partnerships that integrate TK and Western science;
- Research on the indicators prioritized by community observers and how information is shared among community members;
- Better models to train community members in designing and implementing monitoring initiatives;
- The development of models to train Western scientists in collaborating with TK holders and Arctic communities;
- Investing in local institutions that can help support collaborative research;
- Well-resourced projects that help build local institutional capacity to lead and implement projects and compensate community members for involvement in monitoring;
- Documentation and network building among CBM and TK projects across the Arctic.

II. Tools and methods:

There remains a vast, unexplored potential for strengthening monitoring efforts across the Arctic by engaging more communities and encouraging linkages with scientific monitoring programs (Huntington 2008). Often, an investment to build capacity to collect, interpret and manage data is critical to initiating and maximizing such monitoring efforts (Gofman 2010). As is the case in Western scientific approaches to monitoring, many of the potential limitations of CBM can be overcome by careful planning, explicit consideration of likely biases, and thorough training and supervision of participants (Danielsen et al. 2009, Gofman 2010, Kliskey et al. 2009, Luzar et al. 2011). In this section, we review current approaches to data collection, analysis, and integration, and suggest areas for further development.

a) **Data collection**: CBM projects utilize both quantitative and qualitative methods to collect data. As in any monitoring project, the methods used vary depending on the specific phenomena being observed as well as the skills and capacities of those involved in collecting observations. Projects may involve collecting systematic observations using scientific field research methods, photos, journals, drawing, focus groups, and/or interviews to record the traditional knowledge of community experts (Gofman 2010).

CBM that draws on traditional knowledge typically involves eliciting and recording the observations and knowledge of community-identified experts. TK documentation usually includes documenting the wider context surrounding these observations. This is implemented using interviews delivered through any combination of open-format discussion, semi-structured surveys, or structured surveys. TK can also be collected by using journals or diaries kept by village monitors, as in the SIKU ice observation project in Alaska and Russia (Krupnik et al. 2010). The observations should be from vetted individuals who are active harvesters or active resource users, and highly exposed to the phenomena (i.e. high exposure observers) through a long period of familiarity and experience with the place, land, or sea. This process should occur on the community's terms and involve community members in CBM design, data collection and dissemination (see "community engagement").

Many CBM projects adapt technologies so they are easy to use, can reliably capture data in a cold environment, and will record data in a way that is responsive to local ways of interacting with the environment. Projects have successfully adapted and integrated GPS (Gearheard et al. 2011), meteorological equipment (Weatherhead et al. 2010), sea ice monitoring tools (Mahoney et al. 2009), and other technologies for use in riparian and terrestrial ecosystem and wildlife monitoring.

b) **Data analysis:** Once data is gathered through the methods identified above, it is analyzed using quantitative and qualitative analysis methods and techniques, including statistical analysis (SPSS) and thematic identification and coding. Quality assurance and quality control of CBM data are essential elements for robust CBM requiring an established and documented procedure for data entry, error checking, error correction, and data verification. The procedure necessarily involves observers, community coordinators, and scientists working as a team (Alessa et al. 2013). One challenge to analysis of TK data is that current qualitative analysis software packages, such as NVivo and Atlas.ti, can seem complicated, require training and experience, and assume a good understanding of social science methodologies. The development of qualitative analysis tools specifically tailored to monitoring needs would better enable integration of different kinds of data in the analysis process.

CBM can incorporate both western scientific and traditional knowledge approaches as discussed in the previous section. Knowledge co-production requires a thoughtful approach to planning how different kinds of knowledge can be involved in different stages of a project, including in the data analysis phase. Recent biodiversity monitoring processes are proposing ways of integrating and coordinating the methods for knowledge co-production (Gofman 2010, Vongraven et al. 2013). Efforts to identify methods for analysis and integration between Indigenous and scientific knowledge production approaches should continue. The Circumpolar Biodiversity Monitoring Program's (CBMP) strategy identified demonstrating integration examples of CBM with scientific monitoring processes as a priority (Gill et al. 2011, Culp et al. 2013).

c) **Integration and scale:** The methods used for collecting local and traditional knowledge will often determine whether or not the raw or synthesized knowledge can be re-used or contribute towards larger regional, national, and or pan arctic and finally global assessments. Taking the time during the monitoring design phase to consider how methods relate to sharing and use of data at a later stage may enhance the project's value beyond the initial data gathering or monitoring stage (see "sharing, application and use" below).

What's needed to improve tools and methods:

- Identifying, sharing, and improving methods used to effectively gather traditional knowledge for monitoring and observing;
- Identifying best practices in technology adaptation for community use;
- Identifying and refining methods for integrating approaches and data from traditional knowledge and science;
- Developing software for analysis and synthesis of different kinds of data used in CBM;
- Standardized methods toolkits that describe implications for integration and scale.

III. Data and information management

Like all monitoring initiatives, CBM projects generate significant amounts of data and information. Projects that involve local knowledge and respond to locally identified environmental management challenges, however, require both sensitivity and technical skill to manage data effectively. TK documentation often removes this knowledge from the context in which it was developed, posing challenges and questions regarding the feasibility and desirability of knowledge integration (Agrawal 2002). Data must be managed in a culturally sensitive way that promotes sharing when appropriate while ensuring that knowledge holders and communities retain control of their knowledge and data.

The management of data from traditional knowledge occurs at the intersection of numerous, sometimes conflicting norms and legal regimes. These include cultural norms and traditional law as well as Western legal regimes, specifically intellectual property law. Movements and trends in data management that emerge from particular Western scientific contexts, such as the "open data" movement, are not always appropriate for traditional knowledge. Normative and legal frameworks related to data sharing may serve the interests of Indigenous peoples or superimpose incompatible requirements (Young-Ing 2008; Mauro & Hardison 2000; Capistrano & Charles 2012).

In Canada, OCAP principles (Ownership, Control, Access and Possession) have been developed in collaboration with Canadian First Nations communities to prevent the appropriation and misuse of local knowledge (First Nations Centre 2007) by upholding the sovereignty and stewardship of First Nations knowledge holders over their own knowledge and data, which includes the right to determine how it is managed and who it is shared with at all times. Similarly, in the Canadian Inuit context, guidelines have been developed for both communities and researchers to assist with negotiating research relationships (ITK & NRI 1998; ITK & NRI 2007). These initiatives are specific to the communities and institutions that developed them; researchers working with different Arctic Indigenous populations should seek guidance from regional and local governments and institutions on protocols for research collaboration. Projects must respect the rights of communities to control how knowledge will be used, who it will be shared with, and how it will be stored over time (CIHR, NSERC and SSHRC 2010).

There are also technical considerations for the protection of sensitive data. Solutions may include putting systems in place with multiple access roles, data encryption, protection of sensitive locations, and anonymization. Connecting communities and project leaders with organizations like the Exchange for Local Observations and Knowledge of the Arctic (www.eloka-arctic.org), which focus specifically on issues of data management, can help ensure that community requirements for protection of sensitive data are met effectively.

In addition to cultural and legal issues, there are also issues related to technology infrastructure that shape how CBM and traditional knowledge is managed. Access to technology remains an issue for northern communities, and bandwidth speed is considerably slower in the Arctic than in southern research centers. These are considerations that need to be reflected in the development of management plans for storing and sharing data.

Additionally, there are technical considerations related to interoperability that are specific to CBM and traditional knowledge that must be considered. Interoperability issues occur at three levels: 1) data storage format, which includes issues in exchanging different formats and the use of different character sets (e.g. syllabics); data structure, which includes how the data is organized (in flat files or relational databases, for example); and 3) data semantics and "semantic interoperability." The latter relates to the fact that data sets are in fact references to larger systems of meaning and understanding (Wellen and Sieber 2012; Sillitoe 1998), making it perhaps the most difficult issues of data management to address.

A final area to consider is the need for long-term preservation to ensure that data can continue to be accessed over time. Specifically, there is a need to ensure that the individuals and communities who share the results of CBM and LTK documentation projects have continued access to the materials.

What's needed to improve data management:

- Under the leadership of Indigenous communities, establish widely recognized ethical data sharing principles based on the concepts of respect, reciprocity, and responsibility. These principles should be consistent with appropriate legal frameworks, including customary law.
- Establish data management strategies, methods and tool that address the needs and respond to the priorities of Indigenous communities as well as benefiting society as a whole.
- Develop culturally and locally appropriate data management knowledge, skills and infrastructure within Indigenous communities and organizations so that data, information, and knowledge-based resources can be developed and maintained over time.

IV. Sharing, application and use of data:

Application and use of data is a critical dimension of Arctic monitoring, yet one that remains difficult to assess. The use of data relates in part to how widely it is shared, what format it is shared in, and its perceived relevance to critical decision-making issues and challenges. Community-based monitoring is more locally embedded than other types of monitoring, which suggests that the data and information generated through these projects is more likely to be applied in decision-making at a local scale. At the same time, its community-centered nature also means that sharing data and information across scales at the regional or national levels can be more challenging.

Research suggests that greater levels of community engagement in monitoring leads to the information being used in local environmental management and decision-making (Brook et al., 2009; Conrad & Hilchey, 2011). A recent study drawing on a wide review of published literature compared how much time it takes to make a policy decision based on monitoring results in scientist-driven monitoring programs versus community-based monitoring (Danielsen et al. 2010). While it typically takes managers three to five years to implement the recommendations generated through "scientist-executed" monitoring programs, monitoring activities involving local residents are more effective in driving policy changes over a shorter timeframe, often within one year of the data acquisition and analyses. Additionally, while "scientist-executed" monitoring programs drive decisions on regional, national and international levels, they have little impact at a community scale. The authors conclude that increasing the degree of local participation in monitoring efforts increases the speed of decision-making, therefore enhances management responses at local scale (Danielsen et al. 2010).

Another study focused on efficiency of community-based monitoring as compared to conventional methods (Jensen et al. 2007). While the authors examined efforts in a developing country, the realities of remote Arctic communities are often similar to those of developing countries: difficult access, many communities impoverished and disadvantaged with weak local economies and high dependence on natural resources for survival. In this study, two community-based methods, focus group discussion and field diary, were compared with conventional scientific methods, fixed point photography and line-transect. The results showed that for the same recurrent government investment there were more conservation management actions as a result of community-based biodiversity monitoring in comparison with the outcomes of conventional research methods. A combination of both types of monitoring is not only a powerful complementary approach enhancing conservation practices but can also be a cost-cutting mechanism (Jensen et al. 2007).

While these studies present strong evidence that CBM approaches lead to application and use of data at the local level, the links between local projects and information needs at other levels of scale (regional, national, global) remain largely underdeveloped. CBM methods, including integration of TK through qualitative methods such as interviews, can be difficult to translate into data formats that can be aggregated or shared in ways that are relevant for non-local use. There can also be sensitivities related to data ownership and sharing of TK that may prevent programs from sharing data. Additionally, even when community-based projects want to share their data and results, they often lack the resources and network ties that can help build connections to other projects and promote the data and information through conventional scientific methods such as conference presentations and publications. There is therefore a need to invest in network-building initiatives for CBM projects and to explore ways to render different kinds of data and information in formats that can be shared and aggregated as appropriate.

What's needed to improve sharing, application and use of data:

- Further documentation of CBM and TK data that currently exists;
- Investment in strengthening and building networks to connect CBM initiatives;
- Development of standards for data collection and presentation that will enable interoperability and wider sharing of CBM data;
- More robust consideration of how and when CBM data can and should contribute to regional, national, pan arctic, and global assessments.

V. Sustainability and capacity building

One of the most critical aspects of establishing a successful CBM initiative is sustainability. The issue of sustainability must be considered and addressed across a number of themes, including: funding, community interest and motivation, capacity building, and engagement with wider knowledge systems and information sharing.

The very nature of monitoring programs requires long term plans and sustained work; therefore long-term funds must be committed in order for any program to succeed. While the fact may seem obvious, in practice it is rare for CBM projects to find or secure long-term funding.

Funding agencies almost without exception only fund project timelines of a few months to a few years. Multi-year funding can be conditional or dependent on available funds, and renewal of projects beyond the initial multi-year commitment is rare. Communities that do manage to maintain monitoring programs over time often have to piece together funding from various sources. There is a need for funding streams that recognize the nature of monitoring programs and provide long term, multi-year, renewable funding mechanisms for CBM programs.

The short-term and start/stop fate of many CBM initiatives is directly linked to community interest and motivation. Participatory and bottom-up approaches are intended to give local residents significant control over monitoring and engage and interest them for the long term; these efforts are significantly disrupted if a project is cut short or fails due to lack of funding. In such instances, residents can feel frustrated and disheartened, leading to waning interest and motivation.

Lack of sustainable funding is not the only reason for challenges in community interest and motivation. Residents involved in CBM should receive appropriate training, equipment, and infrastructure and other support in order to carry out monitoring efforts. Residents that gain new knowledge and skills from participating in CBM efforts have pride in their work and understand and can teach others about the nature and importance of their monitoring results. Having a sense of ownership of the program motivates CBM observers and workers to maintain and grow the program, thus leading to program stability and sustainability.

Local residents involved in CBM programs are not the only ones that require capacity building for the long-term success of CBM. Partnering scientists, funders and government workers also need to develop new skills, capacities, and knowledge areas that will contribute to successful initiatives. Many of the same issues of turnover of personnel affect government agencies as well as community initiatives; CBM projects suffer when staff who are familiar with these projects and have developed trust with communities are replaced. Partnerships are strongest and most successful when they build on relationships over time and when non-local partners have familiarity with the social and ecological fabric of the community involved.

CBM programs that are networked have the benefit of sharing information that is of local interest (community-to-community sharing). By joining wider networks and linking to other monitoring and scientific research initiatives, community members gain a sense of being part of a wider collective, and gain access to new ideas and resources that can improve techniques and lead to new discoveries. Being part of a larger network can therefore help sustain energy, interest and excitement at the community level.

Finally, there is the need to consider the role of federal funding programs and networks in supporting monitoring initiatives. One challenge, shared with other observing networks, has been the short-term rather than sustained nature of funds through initiatives such as the International Polar Year. Interest in CBM among funding communities is growing; in Canada, funding programs such as the Northern Contaminants Program and ArcticNet have funded CBM projects, while in the US, the Inter-Agency Arctic Research Policy Committee identified engagement of Indigenous knowledge holders and communities in monitoring as one of its priorities for the next five years of Arctic funding (2013 – 2017). While these are positive developments, the challenge of the cyclical nature of government investment remains. Meanwhile, there is also a problem of unequal opportunity to access funding; communities in the Russian Arctic struggle with fewer funding sources to initiate community-based monitoring.

What's needed to improve sustainability and build capacity:

- Funding streams that recognize the nature of monitoring programs and provide long term, multi-year, renewable funding mechanisms for CBM programs;
- Training and capacity building initiatives to develop skills and interest at the community level;
- Attention to issues of capacity and familiarity with community context on the part of research and funding partners;
- Allocation of funding to support the true cost of community participation in monitoring. Community partners should be supported at a level that reflects their central role and that considers the higher costs of living and travel for northern residents.
- Allocation of funding to support networking of CBM activities and projects.

Conclusion:

Community-based monitoring has considerable potential to engage the capacities and knowledge of Arctic residents, including traditional knowledge holders, in support of a robust, international Arctic observing system. In its current state, however, CBM is not yet living up to this potential. Significant work remains to build networks among projects, build capacity for CBM in communities and regions where it remains underdeveloped, refine methods, and develop protocols for sharing data more widely.

Successful implementation of community-based monitoring programs requires on-going partnerships between local communities and academic or government scientists. These partnerships take time to develop and require considerable flexibility, creativity, and commitment from all parties involved. A collaborative approach, sometimes referred to as "knowledge co-production," integrates traditional knowledge and insights from community members along with Western scientific knowledge. Such an approach may result in novel insights informed by Indigenous systems of monitoring, and may lead to the development of data that can be quickly and easily used by decision-makers across various scales. More research and documentation of collaborative approaches to CBM will yield new insights that can strengthen the field. There is also a need to ensure that more formal programs build on and support ongoing monitoring within communities based on traditional knowledge.

Support is needed for the development of new tools, such as for data management, for the research of effectiveness of various methods currently used in community-based monitoring, for training local residents in implementation of monitoring programs and interpretation of their results, and for the opportunities to exchange best practices, new research and innovations in this field. Each of these elements will require robust, sustained funding and committed engagement from the Arctic observing community.

Citations:

Agrawal, A. 2002. Indigenous Knowledge and the Politics of Classificiation. International Social Science Journal 54:287-297.

Alessa, L.N., Kliskey, A., Myers, M., and Veazey, P. 2013. Community Based Observing Networks (CBONs) for Arctic Adaptation and Security. White paper prepared for Arctic Observing Summit, Vancouver, BC.

Alessa, L., Johnson, J., Kliskey, A., Loius, R. 2012. White paper on Indigenous Science.

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., Patton, E. 2011. Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic. *Global Environmental Change* 21(3): 995-1004.

Brook, R. K., Kutz, S. J., Veitch, A. M., Popko, R.A, Elkin, B. T., & Guthrie, G. 2009. Fostering community-based wildlife health monitoring and research in the Canadian North. *EcoHealth*, 6(2), 266–78.

Capistrano, R.C.G. & Charles, A.T. 2012. Indigenous rights and coastal fisheries: A framework of livelihoods, rights and equity. Oceans & Coastal Management, 69: 200-209.

CIHR (Canadian Institutes of Health Research), NSERC (Natural Sciences and Engineering Research Council), and SSHRC (Social Sciences and Humanities Research Council of Canada). 2010. Tri-Council policy statement: Ethical conduct for research involving humans. Ottawa, ON: Canadian Institutes of Health Research. http://www.pre.ethics. gc.ca/pdf/eng/tcps2/TCPS 2 FINAL Web.pdf

Conrad, C. C., & Hilchey, K. G. 2011. A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental monitoring and assessment*, 176(1-4): 273–91.

Culp, J.M., Goedkoop, W., Lento, J., Christoffersen, K.S., Frenzel, S., Guðbergsson, G. *et al*. 2013. Freshwater Biodiversity Monitoring Plan. CAFF Monitoring Series Report No. 7. CAFF International Secretariat, Akureyri.

Danielsen, F., Burgess, N.D. Jensen, P.M., Pirhofer-Walzl, K. 2010. Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. *Journal of Applied Ecology* 47(6):1166-1168.

Danielsen, F., Burgess, N.D., Balmford, A. et al. 2009. Local participation in natural resource monitoring: a characterization of approaches. *Conservation biology: the journal of the Society for Conservation Biology*, 23(1), 31–42.

Danielsen, F., M.M. Mendoza, A. Tagtag et al. 2007. Increasing Conservation Management Action by Involving Local People in Natural Resources Monitoring. Ambio Vol 36, No 7, November 2007, Royal Swedish Academy of Science

Ferguson, M.A.D., Williamson, R.G. & Messier, F. 1998. Inuit Knowledge of Long-term Changes in a Population of Arctic Tundra Caribou. *Arctic* 51: 201-219.

First Nations Centre. 2007. OCAP: Ownership, Control, Access and Possession. Sanctioned by the First Nations Information Governance Committee, Assembly of First Nations. Ottawa: National Aboriginal Health Organization.

Gearheard, S., Aporta, C., Aipellee, G. and O'Keefe, K. 2011. The Igliniit project: Inuit hunters document life on the trail to map and monitor Arctic change. *Canadian Geographer*, 55(1): 42–55.

Gearheard, S., & Shirley, J. 2007. Challenges in community-research relationships: learning from natural science in Nunavut. *Arctic* 60(1): 62-74.

Getz, W.M., Fortmann, L., Cumming, D., du Toit, J., Hilty, J., Martin, R., Murphee, M., Owen-Smith, N., Starfield, A.M., & Westphal, M.I. 1999. Sustaining natural and human capital: villagers and scientists. Science, 283(5409):1855-1856.

Gill, M., Crane, K., Hindrum, R., Arneberg, P., Bysveen, I., Denisenko, N.V. *et al*. 2011. Arctic Marine Biodiversity Monitoring Plan, CAFF Monitoring Series Report No.3, April 2011, CAFF International Secretariat, Akureyri, Iceland.

Gofman, V. 2010. Community based monitoring handbook: lessons from the Arctic. CAFF CBMP Report No. 21. CAFF, Akureyri. CAFF International Secretariat, Akureyri, Iceland.

Huntington, H. 2008. A Strategy for Facilitating and Promoting Community-Based Monitoring Approaches in Arctic Biodiversity Monitoring. CAFF CBMP Report No. 13.

Inuit Tapiriit Kanatami & Nunavut Research Institute (ITK & NRI)

1998 Negotiating Research Relationships: A Guide for Communities. Inuit Tapiriit Kanatami & Nunavut Research Institute.

—

2007 Negotiating Research Relationships with Inuit Communities: A Guide for Researchers. Ottawa & Iqaluit: Inuit Tapiriit Kanatami and Nunavut Research Institute.

Kliskey, A., Alessa, L., and Barr, B. 2009. Integrating local and traditional ecological knowledge for marine resilience. *In* Managing for resilience: new directions for marine ecosystem-based management. K. McLeod and H. Leslie (eds.). Island Press Publishers. Pp. 145–161.

Kofinas, G., with the communities of Aklavik, Arctic Village, Old Crow, and Fort McPherson. 2002. Community contributions to ecological monitoring: Knowledge co-production in the U.S.–Canada Arctic Borderlands. In: Krupnik, I., and Jolly, D., (eds.). The earth is faster now: Indigenous observations of Arctic environmental change. Fairbanks, Alaska: Arctic Research Consortium of the United States. Pp. 54–91.

Krupnik, I., Apangalook, L. Sr., & Apangalook, P. 2010. "It's cold, but not cold enough": Observing ice and climate change in Gambell, Alaska, in IPY 2007 - 2008 and beyond. In Krupnik, I., Aporta, C., Gearheard, S., Laidler, G.J., Holm, L.K. (eds.). SIKU: Knowing our Ice: Documenting Inuit Sea-Ice Knowledge and Use. Dordrecht: Springer. Pp. 81-114.

Laidler, G.J. 2006. Inuit and scientific perspectives on the relationship between sea ice and climate change: the ideal complement? *Climatic Change* 78: 407-444.

Luzar, J.B., Silvius, K.M., Overman, H., Giery, S.T., Read, J.M. & Fragoso, J.M.V. 2011. Large-scale environmental monitoring by Indigenous people. *BioScience* 61: 771-781.

Mahoney, A., Gearheard, S., Oshima, T. and Qillaq, T. 2009. Sea ice measurement thickness from a community-based observing network. *Bulletin of the American Meteorological Society,* March: 370-377.

Mauro, F., & Hardison, P.D. 2000. Traditional knowldege of Indigenous and local communities: International debate and policy initiatives. Ecological Applications, 10(5): 1263-1269.

Mulrennan, M. E., Mark, R. & Scott, C.H. 2012. Revamping community-based conservation through participatory research. *The Canadian Geographer / Le Géographe canadien*, 56(2): 243–259.

Pollock, R. M., & Whitelaw, G.S. 2005. Community-Based Monitoring in Support of Local Sustainability. *Local Environment*, 10(3): 211–228.

Russell, D.E., Svoboda, M. & Folliott, J. 2013. Arctic Borderlands Ecological Knowledge Cooperative: can community interviews inform management? Rangifer [in press].

Sillitoe, P. 1998, The development of Indigenous knowledge: A new applied anthropology. Current Anthropology, 39(2): 223-252.

UNESCO (United Nations Educational, Scientific, and Cultural Organization). 2010. Global change in the Arctic and co-production of knowledge. A report from the International Workshop on Global Change in the Arctic and Co-production of Knowledge - an assessment of recent developments, 27-29 September 2012, Paris, France. URL: http://www.unesco.org/new/en/natural-sciences/priority-areas/links/single-view-indigenous-peoples/news/global_change_in_the_arctic_and_co_production_of_knowledge/.

Vongraven, D., Aars, J., Amstrup, S., Atkinson, S., Belikov, S., Born, E. *et al*. 2013. A circumpolar monitoring plan for polar bears. *Ursus* 5: 66.

Weatherhead, E., Gearheard, S. & Barry, R.G. 2010. Changes in weather persistence: Insight from Inuit knowledge. *Global Environmental Change* 20: 523-528.

Wellen, C.C. & Sieber, R.E. 2013. Toward an inclusive semantic interoperability: the case of Cree hydrographic features. *International Journal of Geographical Information Science*. 27(1):168-191.

Young-Ing, G. 2008. Conflicts, discourse, negotiations and pro- posed solutions regarding transformation of traditional knowledge. In R. Hulan and R. Eigenbrod (eds.) Aboriginal Oral Traditions: Theory, Practice, Ethics. Black Point, NS: Fernwood Publishing. Pp. 61–78.