INDIGENOUS KNOWLEDGE SYSTEMS AND CROSS-CULTURAL RESEARCH

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The initiatives outlined in this article are intended to advance our understanding of cultural processes as they occur in diverse community contexts, as well as contribute to the further conceptualization, critique, and development of Indigenous Knowledge Systems in their own right. Just as those same initiatives have drawn from the experiences of Indigenous Peoples from around the world, the organizations and personnel associated with this article have played a lead role in developing the emerging theoretical and evidentiary underpinnings on which the associated research is based. The expansion of the knowledge base that is associated with the interaction between western science and Indigenous Knowledge Systems will contribute to an emerging body of scholarly work regarding the critical role that local observations and Indigenous Knowledge can play in deepening our understanding of human and ecological processes, particularly in reference to the experiences of Indigenous Peoples.

This White Paper addresses issues of relevance to underserved populations in Alaska, the Arctic and other geographic regions inhabited by Indigenous Peoples. It provides a much-needed impetus toward organizing research and education support structures that contribute to the broadening of an infrastructure fostering the use of multiple knowledge systems and diverse approaches to research. The international scope of the initiatives described provides multiple benefits derived from the economies of scale associated with linking numerous small-scale populations, as well as increased generalizability of outcomes associated with the extensive opportunities for cross-cultural comparison.

Indigenous Peoples of the circumpolar north have been caretakers of the land for millennia and thus have acquired extensive deep knowledge regarding the environment in which they live. Furthermore, Indigenous residents of the Arctic and subarctic regions have been at the forefront of debates about the impacts and responses to accelerating ecological changes. The Alaska Observation Summit (AOS) provides an opportunity to forge more meaningful institutional and collaborative research links with Indigenous communities and to entrain and support emerging Indigenous scholars. It was clear that implementing a successful research program requires working closely with Indigenous stakeholders in all phases of developing and implementing an Indigenous research agenda.

Some of the near- and long-term goals of Indigenous-driven cross-cultural research are as follows: (1) develop a strategy and support activities to increase the numbers of Alaska Native graduate and undergraduate students in underrepresented fields of scientific research; (2) foster inclusion of Alaska Native perspectives in planning and research activities at UAF that have implications for Native people and communities, including seeking funding to engage Native graduate students in affiliation with such research initiatives; (3) work with researchers to insure compliance with protocols for cultural and intellectual property rights, including the Principles for the Conduct of Research in the Arctic and the Research Guidelines of the Alaska Federation of Natives (http://www.ankn.uaf.edu/rights.html); and (4) help implement a program of graduate fellowships and residencies to enhance exchange between Arctic Indigenous Peoples, and between Indigenous and western perspectives on topics of relevance to the circumpolar north.

In Pursuit of Indigenous Research Methodologies

The graduate education initiatives outlined here integrate the tools and approaches of the natural and social sciences in a cross-cultural and interdisciplinary framework for analysis to better understand the emerging dynamic between Indigenous Knowledge systems and western science. The focus is on the interface between Indigenous knowledge and research on an international scale, with opportunities for collaboration among Indigenous Peoples from throughout the major Indigenous regions of the world. The emphasis is on engaging a new generation of Indigenous PhD's by providing support for a cohort of Indigenous graduate students and scholars who can effectively integrate multiple cultural perspectives. In so doing, we are pursuing the development of a deeper understanding of Indigenous Knowledge systems as they relate to conceptions of research and the application of that understanding to contemporary issues, particularly in the context of Indigenous research initiatives. It also draws and builds upon past and current Indigenous research initiatives that have sought to utilize Indigenous Knowledge to strengthen the research and pedagogical practices in K-16 education.

With numerous research initiatives currently in various stages of development and implementation that revolve around themes that drive The University of Alaska Fairbanks (UAF) engagement with Indigenous research, there is an unprecedented window of opportunity to open new channels of communication between scientists and Indigenous communities, particularly as they relate to those research activities that are of the most consequence to Indigenous Peoples (e.g., effects of climate change, environmental degradation, contaminants and subsistence resources, health and nutrition, bio/cultural diversity, natural resource management, economic development, resilience and adaptation, community viability, cultural sustainability, language education, etc.). To the extent that there are competing bodies of knowledge (Indigenous and western) that have bearing on a comprehensive understanding of particular research initiatives associated with the Indigenous themes, we seek to provide an opportunity for faculty and students to embed an Indigenous perspective within their graduate research initiatives to contribute to and learn from a collaborative research process.

Given the range of interdisciplinary applications and research topics that come into play at the interface between Indigenous and western knowledge systems, the UAF Indigenous Studies PhD program has been structured to insure that students achieve both breadth and depth in their graduate studies. This is accomplished by requiring all students to complete a set of core courses, coupled with specialization from a choice of six emphasis areas:

- Indigenous Knowledge Systems
- Indigenous Research
- Indigenous Languages
- Indigenous Pedagogy/Education
- Indigenous Leadership
- Indigenous Sustainability

By providing graduate fellowships and support for a cohort of Indigenous PhD candidates who are matched with various research initiatives, while at the same time they are engaged in an articulated course of graduate studies focusing on the Indigenous Knowledge theme, we are preparing a new generation of scholars whose legacy will extend well beyond the projected time frame of the current research initiatives. The crosscutting nature of

Indigenous knowledge systems provides opportunities to not only deepen our understanding within particular thematic areas, but also to better understand processes of interaction across and between thematic areas.

Much research has been done in recent years on identifying discrete features of Indigenous knowledge systems that are recognized as having scientific relevance and application in various fields (Krupnik and Jolly, 2005). However, few cultural insiders have engaged in systematic studies of Indigenous Knowledge systems to identify the underlying epistemological structures that connect those discrete elements together and the processes by which the knowledge is accrued, adapted and passed on to succeeding generations (Kawagley, 1995). By addressing these latter considerations, we are confronting some of the most long-standing educational, social, and political challenges in Indigenous societies around the world.

In addition to conducting research on the inner dynamics of Indigenous Knowledge systems, the graduate students (and associated faculty) are also examining the interplay between Indigenous and western knowledge systems, particularly as it relates to processes of knowledge construction and utilization. Given the complexities that have arisen from the intermingling of disparate systems of thought and ways of knowing on a global scale, it is essential that the issues be addressed in a coordinated, comparative, cross-cultural and cross-disciplinary manner. We are seeking to take advantage of the geographic context and cultural diversity of Alaska and the research strengths that have been developed over the past 30 years at the University of Alaska Fairbanks (UAF) to assemble a comprehensive research agenda and strategy that will meet the challenge before us. As the only PhD-granting institution in Alaska, UAF serves as the lead institution in the development of the described initiatives, in cooperation with related strategically distributed partner institutions with distinguished reputations in Indigenous scholarship.

Alaska, including UAF, has been at the forefront in bringing Indigenous perspectives into a variety of policy arenas through a wide range of research and development initiatives in recent years. From 1995 to 2005, the National Science Foundation supported the implementation of the Alaska Rural Systemic Initiative, a joint effort of the Alaska Federation of Natives and UAF's Center for Cross-Cultural Studies (CXCS), to integrate Indigenous Knowledge and pedagogical practices into all aspects of the education system, K-20 (the Alaska Rural Systemic Initiative, AKRSI, 2005). Through this effort, a network of partner schools and communities throughout Alaska has been formed, providing a fertile real-world context in which to address many of the research issues associated with Indigenous Knowledge systems outlined above. In the past few years alone, the National Science Foundation has funded projects incorporating Indigenous Knowledge in the study of climate change, the development of indigenous-based math curriculum, a geo-spatial mapping program, the effects of contaminants on subsistence foods, observations of the aurora, and alternative technology for waste disposal. A major limitation in all these endeavors, however, has been the lack of Indigenous People with advanced degrees and research experience to bring balance to the Indigenous Knowledge/western science research enterprise.

One of the long-term purposes of the current initiatives is to develop a sustainable research infrastructure that makes effective use of the rich cultural and natural environments of Indigenous Peoples to implement an array of intensive and comparative research initiatives, with partnerships and collaborations in Indigenous communities across the U.S.

and around the Indigenous world. The initiatives outlined in this article are intended to bring together the resources of Indigenous-serving institutions and the communities they serve to forge new configurations and collaborations that break through the limitations associated with conventional paradigms of scientific research. Alaska, along with other participating Indigenous regions, provides a natural laboratory in which Indigenous graduate students and scholars can get first-hand experience integrating the study of Indigenous Knowledge systems and western science.

Cultivating an Interdisciplinary Research Culture

The heart of the Indigenous Knowledge systems research initiative is made up of a cohort of PhD students enrolled in the newly created UAF Indigenous Studies PhD program, established in 2009 and currently enrolling 30 students distributed throughout Alaska and extending to students across the country through a distance education delivery system. Through the research requirements associated with a series of PhD graduate fellowships, we have recruited a cohort of PhD students with an interdisciplinary interest in the theme of Indigenous Knowledge systems and scientific research. These students, along with the Center for Cross-Cultural Studies (CXCS) and the Alaska Native Knowledge Network (ANKN) faculty, are responsible for implementing a series of research initiatives that address the core themes associated with cultivating a culture of Indigenous research as applied to Indigenous Knowledge systems and related research practice in a cross-cultural context.

Both the Indigenous Knowledge systems and research initiatives are intended to offer and guide research opportunities for a cohort of current and aspiring scholars. All students are expected to participate in a common course of study associated with the broad theme of Indigenous Knowledge systems, plus each student is required to choose an area of relevant studies in which they achieve in-depth expertise through participation in related research initiatives. Coursework to achieve both the breadth and depth requirements is taken through a combination of existing and newly developed UAF and partner institution course offerings, along with special seminars, distance education programs, visiting scholars, international exchanges, internships, and Indigenous elders' academies sponsored by the participating institutions. Following are examples of the core courses that students can choose from:

CCS 601, Documenting Indigenous Knowledge
CCS 608, Indigenous Knowledge Systems
CCS 610, Educational and Cultural Processes
CCS 611, Culture, Cognition and Knowledge Acquisition
CCS 612, Traditional Ecological Knowledge
CCS 602, Cultural and Intelligence Property Rights
CCS 631, Culture, Community and Curriculum

In addition to students having the opportunity to enroll in existing UAF courses through extended modes of instruction, they are also able to access expertise from cooperating partner institutions, as well as identify a scholar with whom they become associated who will serve as a mentor and member of their graduate advisory committee to help guide their research in ways that foster cross-disciplinary collaboration and comparative analysis. At the same time, students engaged in related research will be eligible to participate in UAF-sponsored programs and research initiatives with a comparable goal of promoting scholarly cross-fertilization and synergy around the Indigenous Knowledge systems and ethical research theme. Video and audio conferencing and internet-based technologies are utilized to support an array of course offerings and joint seminars on topics of interest to an interdisciplinary audience. Such shared course offerings linking faculty and students across multiple institutions have already been implemented and the infrastructure is in place to expand to further topics.

Each partner program and institution brings a unique perspective to the research arena that serves to inform and expand the capacity of the overall effort. Other institutions or researchers beyond those directly associated with the Indigenous Knowledge research initiative are able to participate in and contribute to the initiatives as affiliates. Following is a brief description of some of the capabilities, programmatic functions and research topics that are associated with each of the participants. The key elements include building the capacity of Indigenous graduate students to create an international Indigenous graduate network in which students are challenged to become transformative knowledge mobilizers.

Related Resources and Initiatives

In January 2005, the University of Alaska Fairbanks organized an international *Indigenous Knowledge Systems Research Colloquium,* which was held at the University of British Columbia (UBC), bringing together a representative group of Indigenous scholars from the United States, Canada, and New Zealand “to identify salient issues and map out a research strategy and agenda to extend our current understanding of the processes that occur within and at the intersection of diverse world views and knowledge systems.” A second gathering of Indigenous scholars took place in March 2005, focusing on the theme of “*Native Pedagogy, Power, and Place: Strengthening Mathematics and Science Education through Indigenous Knowledge and Ways of Knowing.”* The following is a list of research topics identified by the participants in these two events as warranting further elucidation as they relate to our understanding of the role of Indigenous Knowledge systems with regard to contemporary research and also to educational contexts:

Native Ways of Knowing	Indigenous Language Learning
Culture, Identity and Cognition	Ethno-mathematics
Place-based Learning/Sense of Place	Oral Tradition/Story Telling & Metaphor
Indigenous Epistemologies	Disciplinary Structures in Education
Indigenizing Research Methods	Cultural Systems and Complexity Theory
Cross-generational Learning	Ceremonies/Rites of Passage
Culturally Responsive Pedagogy	Technologically Mediated Learning
Native Science/Sense Making	Cultural & Intellectual Property Rights

Drawing on the seminal work of the distinguished scholars who participated in these gatherings, the research agenda outlined above is intended to advance our understanding of the existing knowledge base associated with Indigenous Knowledge systems. Likewise, the agenda will contribute to an emerging international body of scholarly work regarding the critical role that local knowledge can play in our understanding of global issues (Barnhardt and Kawagley 2005).

Alaska Natives have been at the forefront in bringing Indigenous perspectives into a variety of policy arenas through a wide range of research and development initiatives. In addition, Native people have formed new institutions of their own (Consortium for Alaska Native Higher Education, Alaska Native Science Commission and the First Alaskans Institute) to address some of these same issues through an indigenous lens.

One of the long-term purposes of this approach is to develop a sustainable research infrastructure that makes effective use of the rich cultural and natural environments of Indigenous Peoples in order to implement an array of intensive and comparative research, partnerships and collaborations within indigenous communities across the U.S. and around the circumpolar world. These initiatives are intended to bring together the resources of indigenous-serving institutions and the communities they serve to forge new configurations and collaborations that break through the limitations associated with conventional paradigms of scientific research. Alaska, along with each of the other participating Indigenous regions, provides a natural laboratory in which Indigenous graduate students and scholars can get first-hand experience integrating the study of Indigenous Knowledge systems and western science.

The timing of these initiatives is particularly significant as it provides a pulse of activity that capitalizes on new Indigenous-oriented academic offerings that are emerging in institutions around the world (Alaska Native Knowledge Network 2015).

While the University of Alaska Fairbanks has had a dismal track record of graduating only 15 Alaska Natives with a PhD over its entire 100-year history, there is now a strong push, due in large part to the initiative of Alaska Native students and leaders, to bring more resources to bear on this issue. This includes drawing upon programs and institutions from around the world to provide student's with an opportunity to access expertise from a variety of Indigenous settings, as well as to identify Indigenous scholars who might serve as members of their graduate advisory committees and to help guide their research in ways that foster cross-institutional, interdisciplinary and comparative analysis.

At the same time, students from partner institutions engaged in related research are eligible to participate in UAF-sponsored courses and research initiatives with a comparable goal of promoting scholarly cross-fertilization and synergy. Each partner institution brings a unique perspective to the research initiatives that serve to inform and expand the capacity of the overall effort. Close attention is also given to addressing issues associated with ethical and responsible conduct in research across cultures and nations, employing the 'Mataatua Declaration on Cultural and Intellectual Property Rights of Indigenous People," "Principles for the Conduct of Research in the Arctic," and the "Guidelines for Respecting Cultural Knowledge" (Alaska Native Knowledge Network 2001).

World Indigenous Nations Higher Education Consortium

The international partnerships associated with this endeavor are essential to its success, particularly as it relates to gaining a deeper understanding of the relationship between Indigenous Knowledge systems and western scientific research. The primary benefits to be derived from cross-institutional collaboration on research related to Indigenous Knowledge systems are the opportunities for scholars and graduate students to engage in cross-cultural analysis of data from diverse Indigenous settings to delineate what is particular to a given situation vs. what is generalizable across Indigenous populations and beyond. There are also considerable economies of scale and synergistic benefits to be gained from such collaborations, since many of the Indigenous populations are relatively small in number and thus are seldom able to engage in large-scale research endeavors on their own.

The primary vehicle by which these Indigenous collaborations are being implemented is through UAF's charter membership in the International Indigenous Graduate Education Alliance (IIGEA), which was established in 2009 under the auspices of the World Indigenous

Nations Higher Education Consortium (WINHEC). The members of IIGEA have formed an alliance which includes the following commitments:

> With this Memorandum of Understanding, the participating Indigenous-serving universities agree to join with the World Indigenous Nations Higher Education Consortium in forming a partnership for exchanging information and for developing cooperative research programs and activities in the areas of graduate education, professional faculty development, and research broadly related to the education of Indigenous People.

In addition to facilitating cooperative research programs on an international scale, WINHEC has established an Indigenous accreditation process for Indigenous-serving programs and institutions, and, most recently, WINHEC has formed a World Indigenous Nations University (WINU) dedicated to the principles outlined in the *United Nations Declaration on the Rights of Indigenous Peoples*.

University of the Arctic

Of particular relevance in establishing international linkages for the IKS research initiative is the long-standing association of UAF with the University of the Arctic (UArctic), which is a cooperative network of universities, colleges, and other organizations committed to higher education and research in the North. Members share resources, facilities, and expertise to build postsecondary education programs that are relevant and accessible to northern students. The overall goal is "to create a strong, sustainable circumpolar region by empowering northerners and northern communities through education and shared knowledge" (UArctic Strategic Plan, 2010). With the UArctic infrastructure already in place and with UAF serving in a leadership role across the circumpolar region, UArctic serves as a close collaborator in the implementation of the IKS research initiatives, particularly as it relates to support for Indigenous contributions to the research efforts.

In addition to the networks of institutions listed above, there are many other institutions and scholars across Alaska and beyond who have much to contribute to and gain from the work of the IKS research initiatives. Within the U.S., affiliation with organizations such as the U.S. Tribal Colleges extends the reach of the IKS networks to other cultural groups with similar interests. IKS research reaches out to potential institutional and/or individual contributors to the IKS initiatives and incorporates them in regional symposia, collaborative research endeavors, international exchanges, shared course offerings, joint seminars, etc.

Indigenous Knowledge Research Consortium

Overall coordination and implementation occurs through an Indigenous Knowledge Research Consortium (IKRC) made up of representatives from participating institutions. Extensive use of telecommunications technology (e-mail, listserv, web, teleconference) provides the essential communication and dissemination links among the various partners, supplemented by meetings that bring all the partners together in a face-to-face context to facilitate planning collaboration, cross-fertilization and dissemination of initiatives. Given the scope of the research agenda and support activities associated with the Indigenous Knowledge systems research initiatives, the IKRC serves as the vehicle by which the various networks and research strands are linked together and coordinated.

The Indigenous Knowledge Research Consortium also provides opportunities for graduate students engaged in Indigenous-related research to link with one another through a coordinated set of course offerings, seminars, exchanges and collaborative research endeavors that give students access to Indigenous Knowledge, resources and communities on an international scale. Through the use of distance education modalities, the internet and teleconferencing capabilities, students are able to draw on the resources of all the collaborating programs to enrich their graduate studies and research activities. UAF and participating members of the WINHEC International Indigenous Graduate Education Alliance contribute to scaling up the networking model of the Alaska Native Knowledge Network web site (http://www.ankn.uaf.edu), newsletter, publications, curriculum resources, etc., and apply it at an international level to serve as an all-purpose resource for information related to Indigenous cultures, communities and educational practices. Participation in the IIGEA functions as a two-way exchange with UAF students accessing resources from other institutions and participants from other institutions accessing UAF resources.

Doctoral Research Fellowships

A limited number of Doctoral Research Fellowships and travel support are included in the PhD program as essential elements that provide students the opportunity to step back from day-to-day demands in their local context and immerse themselves in their graduate studies and research so they can complete a program in a reasonable timeframe. The intent is to provide support for an on-going cohort of doctoral students with each candidate receiving support for up to three years. We also welcome students from other institutions who may wish to participate in the Indigenous research program and course offerings under UAF sponsorship.

In addition to Indigenous research fellows having the opportunity to enroll in a cooperating partner institution with a strong Indigenous emphasis, they are also expected to identify an indigenous scholar from that institution who can serve as a member of the graduate advisory committee to help guide the research in ways that foster cross-institutional collaboration and comparative analysis of research issues. At the same time, students from partner institutions are engaged in related research to be eligible to attend other affiliated institutions with a comparable goal of scholarly cross-fertilization and synergy around the Indigenous research themes.

A primary emphasis in the recruitment of doctoral research fellows for the Indigenous Studies program is based on attracting Indigenous candidates from throughout all the participating cultural regions, including Alaskans, Native Americans, Native Hawaiians, Canadian First Nations, Greenlandic Inuit, Scandinavian Sami, Australian Aborigines, and others from around the Indigenous world who have in-depth experience in Indigenous settings. This is so that the Indigenous cohort represents multiple cultural perspectives which can be brought to bear on the themes of the indigenous research program outlined above. One of the key incentives for initiating the research and education program at UAF has been to address the severe shortage of Alaska Natives with advanced degrees who can assume critical faculty roles and research responsibilities throughout the state. Video and audio teleconferencing is also utilized extensively to support an array of course offerings and joint seminars on topics of interest to a cross-institutional audience. At UAF, the courses, CCS 601 (Documenting Indigenous Knowledge), CCS 602 (Cultural and Intellectual Property Rights) and CCS 690 (Seminar in Cross-Cultural Studies) address issues associated with ethical and responsible conduct in research across cultures.

Institutional Roles and Responsibilities

The University of Alaska Fairbanks has adopted as one of its major strategic goals to "serve as the premiere higher educational center for Alaska Natives," and historically has been the lead higher education institution in Alaska providing programs addressing Indigenous issues. The Center for Cross-Cultural Studies, which serves as the institutional home base for the Indigenous research initiative, was established by the University of Alaska Board of Regents in 1971 as a teaching, research, and development unit to promote programs that concentrate on the needs of Alaska's Indigenous societies, with particular regard to educational needs and issues in rural Alaska. Accordingly, objectives of CXCS are to offer academic degree programs and coursework in cross-cultural studies; design and conduct basic and applied research projects; develop, conduct and evaluate alternative educational strategies; and disseminate findings on current Alaska research in cross-cultural studies.

In recent years, most of the work carried out under the auspices of the Center for Cross-Cultural Studies has revolved around the newly created PhD program in Indigenous Studies and the contractual work associated with the Alaska Rural Systemic Initiative. Both of these endeavors have opened up new avenues to expand our knowledge base in areas related to the study of Indigenous Knowledge systems, most significantly by attracting and preparing the first generation of Alaska Native graduate students, at least 35 of whom are now engaged in pursuing further advanced studies and research.

In addition, we have participated in numerous national and international conferences and symposia on related issues through which we have formed alliances with other programs and institutions engaged in similar endeavors, many of which have agreed to contribute to the WINHEC International Indigenous Graduate Education Alliance initiatives. Through its efforts, UAF is assuming a lead role in linking together these numerous localized endeavors to form a synergistic relationship that enhances the capacity of all the participating institutions and personnel to achieve goals we cannot achieve alone. Each of the partner institutions shares a common commitment to the overall goals of the various research initiatives, but each have also evolved in ways that adapt to the cultural and institutional milieu in which they are situated, so the partnership structure is critical to establishing the parameters and responsibilities for the implementation of each of the regional networks and research programs. In addition, the strategy for engagement of partner institutions in each region is incorporated into the planning and implementation process at the regional level, building on the research focus and strengths of each site.

Sustainability

An underlying theme of these initiatives has been the need to reconstitute the relationship between Indigenous Peoples and the host societies in which they are embedded by documenting the integrity of locally situated cultural knowledge and skills and critiquing the learning processes by which that knowledge is transmitted, acquired and utilized. To overcome the long-standing estrangement between indigenous communities and the external institutions through which they have been reshaped, all parties in this endeavor (community, school, higher education, state and national agencies) need to form a true multi-lateral partnership in which mutual respect is accorded the contributions that each brings to the relationship. The key to overcoming the historical imbalance in that regard is the development of an Indigenous–driven research process that focuses on the role of Indigenous

Knowledge systems, with primary direction coming from Indigenous communities, so that Indigenous People are able to move from a passive role subject to someone else's agenda to an active leadership position with explicit authority in the construction and implementation of the research initiatives. The willingness of the partner institutions to enter into this partnership represents a significant milestone in the relationship between educational institutions and Indigenous communities around the world, and it is to insuring that it becomes a truly reciprocal relationship of mutual benefit that much of the efforts are directed.

In this context, the task of achieving sustainability hinges on our ability to demonstrate that such an undertaking has relevance and meaning in the local Indigenous contexts with which we are associated, as well as in the broader social, political, and educational arenas involved. By utilizing research strategies that link the Indigenous ways of knowing already established in the local community and culture, Indigenous People are more likely to find value in what emerges and be able to put the new insights into practice toward achieving their own ends. In turn, the knowledge gained from these efforts will have applicability in furthering our understanding of basic human processes associated with research and the transmission of knowledge in all forms. By bringing the research expertise and educational capabilities of the higher education institutions into direct involvement with Indigenous communities, the initiatives serve a capacity-building function with potential "multiplier effects" for indigenous communities in areas with disproportionate levels of underdevelopment on a range of socio-economic indices, e.g., improvements in health, education, and economic well-being.

All of the above contributes to the development of new insights that increase our understanding of how Indigenous Knowledge systems function in relation to the cultural context in which they are situated. By focusing on an interdisciplinary, cross-institutional, and cross-cultural research endeavor toward a common goal with a carefully articulated, and unified strategy, we are well positioned to ensure that the work will move forward on a pathway toward becoming self-sufficient and sustainable into the future.

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Community-based monitoring and assessment to foster human rights protections and community resilience in Alaska

Robin Bronen

Extreme weather events combined with decreased arctic sea ice and thawing permafrost are causing accelerating rates of erosion in Alaska Native communities located along the western coast of Alaska. These climate-induced environmental changes are causing Alaska Native communities to choose the relocation of their entire community as the only long-term adaptation strategy that can protect their culture and subsistence lifestyles. Preventive relocations, which occur prior to an extreme weather event that causes land to permanently disappear and displaces populations, can be a critical disaster risk reduction tool that can save lives and offer long-term protection. No institutional mechanism currently exists in the United States, or anywhere in the world, to determine when a preventive relocation should occur, who should make this decision, or how the decision should be made. Community-based social-ecological monitoring and assessment tools may be a critical mechanism to determine whether and when relocations need to occur.

International law requires nation state governments to protect vulnerable populations from climate-induced environmental change. The government responsibility to protect people through the implementation of preventive relocations may require relocation against people's will (Ferris 2012). However, government-mandated relocations have been uniformly disastrous for the people relocated. Development projects, particularly dams, have displaced approximately 280–300 million people between 1990 and 2010 (Ferris 2012). Governments have also forcibly relocated people for geopolitical motives (Tester and Kulchyski 1994). During World War II, the U.S. government forcibly relocated Alaska Natives living on the Aleutian Islands, theoretically to protect them from the Japanese (Mobley 2012). These government-mandated relocations weaken social, cultural, and political institutions, disrupt subsistence and economic systems, and affect the culture and traditional kinship ties within a community (Jha 2010). In Alaska, the forcible relocation of the Aleuts caused the death of approximately 10% of the relocated population.

To address both the severe consequences of government-mandated relocations and the lack of a methodology to assess climate change risk in relation to the ability of people to remain where they currently live, I propose the design of an adaptive governance relocation framework. One component of such a framework is a social-ecological monitoring and assessment tool.

An adaptive governance framework means that governance institutions can respond dynamically to environmental changes and can shift their efforts from protection in place to managed retreat and community relocation (Bronen 2011, Bronen and Chapin 2013). A community-based social-ecological monitoring assessment tool that can engage community residents in a collaborative decision-making process with government representatives to determine whether and when to relocate may avoid or minimize the harmful effects of government-mandated relocations and can foster the protection of human rights. Human rights must be embedded in any relocation process to ensure that people will not suffer as a result of the permanent loss of home. Community-based social-ecological monitoring and assessing can foster human rights protections so that community residents are empowered with the information they need to determine whether, when and how relocation needs to occur.

Community-based integrated assessments can foster empowerment, promote human rights protections, and encourage transparent decision-making processes, all of which are elements of good governance (Alfredsson 2013). Human rights principles, based on the fundamental freedoms inherent in human dignity, can be an important foundation on which adaptation strategies are designed and implemented (Moyn 2010, Bronen 2011, Tanner et al. 2015). The right to self-determination is the most important human rights principle to guide climate change adaptation. In the context of climate-induced environmental change that threatens the habitability of the places where people live, self-determination means that people have the right to make decisions regarding adaptation strategies (Bronen 2011, 2014). The right to self-determination also means that people have the right to make fundamental decisions about when, how, where, and if relocation occurs to protect them from climate-induced environmental threats. To operationalize this right, people need the capacity to assess and document the environmental changes and sociological effects and vulnerabilities caused by climate change (May and Plummer 2011). However, the ability of this community-based process to foster human rights will depend on the capacity of governance institutions to collaborate, be transparent in decision-making, and be inclusive of all sectors of society.

Designing and implementing adaptation strategies also require the involvement of multi-level institutions. Community-based integrated social-ecological assessments can facilitate communication between community residents and local, state, regional, and national actors who can bring technical expertise that may not exist at the local level to better assess and implement adaptation strategies. Local knowledge can provide not only a long-term historical perspective, but an understanding of the connections between people and the environment, while Western scientific approaches can generate projections of future change in the context of broader global scientific data analysis (Kannen and Forbes 2011). Through this collaborative data-gathering process, local scenarios can be integrated into regional or national models of climate change scenarios (Lewis 2012). In this way, both residents and government agencies can anticipate vulnerability to implement a dynamic and locally informed institutional response.

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Understanding observations of selected environmental changes in communities surrounding the Bering Sea

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ABSTRACT

Data in remote Arctic communities is sparse and can be unreliable. Proposals have been made to use Community-Based Observing Network and Systems (CBONS) as human sensor-arrays to increase collection of data and knowledge in the Arctic. Cognitive neuroscience suggests that natural selection has not shaped our perceptions to be an accurate representation of objective reality, but to be a species-specific guide to behaviors that we need to survive and reproduce. An understanding of which human perceptions are more or less reliable is essential if human-arrays are to be used. This study sought to investigate the correspondence between observations made by community members selected based on their length of residence or amount of time spent on the land and the sea, to local instrumented data. Interviews were conducted in communities bordering the Bering Sea in the Russian Federation: Nikolskoye, Tymlat and Kanchalan; and in Alaska: St. George, Togiak, Sand Point, Savoonga and Gambell.

Survey participants answered questions about a wide range of environmental changes. We selected environmental changes for comparison only if robust instrumented data records existed with which to compare them. The environmental variables that met those criteria were: air temperature, changes in vegetation, and freeze up and break up of sea ice surrounding St. Lawrence Island. We examined the correspondence of community-based (local) knowledge and instrumented data. The results suggest that observable stimuli that are tied to ability to gather food and to safety are more accurately perceived and that high variability in stimuli makes accurate perception difficult.

INTRODUCTION

Considerable scientific monitoring has been conducted in the Arctic; including ocean surface current sensors, buoy networks, and subsurface glider observations at sea; and terrestrial gauges, and meteorological stations on land. Instrumented records of environmental conditions in Alaska present challenges. The geographic area of Alaska and the Arctic is immense. Gauges are inadequate to reliably monitor environmental changes because they are sparse and are often placed in populated areas and near-shore locations which are easy to access and maintain. As a result, there is very little instrumented data at fine scales (Alexander et al. 2011) causing inconsistencies between instrumented data and community-based observations. Additionally, records often do not extend far back in time, or are kept for a limited time period and are then discontinued (NRC 2006).

Increasing the number of observations in the Arctic is critical since it is a bellwether of climate change. Incorporating Community-Based Observing Networks and Systems (CBONS) into a "data web"; a human sensor-array creating a network of observation stations across the Arctic, would improve data availability as well as response to change in the Arctic. Observing Networks are currently used to observe arctic events and changes as part of scientific monitoring efforts (Alessa et al. 2015). In Alaska these include, but are not limited to, the Arctic Ocean Observing System, the Global Ocean Observing System, the Arctic Observing Network, and the Sustaining Arctic Observing Network for global level efforts (Alaska Ocean Observing System 2015). There is increasing interest to augment and enhance these observing networks with CBONS, that could potentially allow observations based on scientific instruments to be coupled with local community-based observations of change.

The Bering Sea Sub-Network: A Distributed Human Sensor Array to Detect Arctic Environmental Change (BSSN) was an international community-based observation alliance for the Arctic Observing Network. This project was initiated to improve knowledge of environmental changes occurring in the Bering Sea in order to enable Arctic communities, governments and scientists to predict, plan and respond to these changes. The BSSN and its successor, the Community-based Observing Network for Adaptation and Security (CONAS), is composed of eight indigenous communities bordering the Bering Sea in the Russian Federation and Alaska, USA. In Russia participating communities are Nikolskoye (Western Aleut/Unangas), Tymlat (Koryak), and Kanchalan (Chukchi); in Alaska participating communities include Gambell, (Siberian Yupik), Savoonga (Siberian Yupik), Togiak (Central Yup'ik), St. George (Eastern Aleut/Unangan), and Sand Point (Eastern Aleut/Unangan). All communities are dependent on subsistence resources from the productive Bering Sea.

Figure 1: Map of communities surveyed and assessed for environmental change.

Knowledge contributed by CBONS is predominantly local place-based knowledge (LPBK) that, in the communities included in this study, also incorporates Indigenous Knowledge (IK). In this paper, because of the demographics of the communities included in the study, we use the terms community-based knowledge and local place-based knowledge synonymously. In a changing Arctic LPBK has much to offer, although integration with dominant Western scientific tradition can be difficult. Integration challenges have led to the underutilization of this knowledge (Huntington et al. 2004). Nonetheless, LPBK has made contributions to adaptation research by elucidating vulnerability to environmental change and exploring appropriate adaptive actions and interventions (Brubaker et al. 2011, Collings 2011, Ford & Pearce 2012, Pearce et al. 2009, Riedlinger 2001, Tremblay et al. 2007). Beyond expanding data availability, other important goals of LPBK research include: 1) shaping policies toward greater relevance to those affected (Ford et al 2010, Mahoney et al 2009, Meek et al. 2008); 2) more equitable power sharing by co-producing knowledge (Gearheard & Shirley 2007); 3) contributing to an understanding of social processes that relate to use of natural resources (Wolfe et al 2007); 4) providing alternative perspectives of ecological change (Berkes et al 2007); 5) guiding scientific inquiry (Carmack & MacDonald 2008), and; 6) capacity and relationship building (Pearce et al. 2009).

Local place-based knowledge (Indigenous Knowledge and Traditional Ecological Knowledge) and Western science instrument-derived data

Traditional Ecological Knowledge (TEK) is a subset of LPBK that relates specifically to ecology. Traditional Ecological Knowledge and Western science are similar because both are based on an accumulation of observations, but there are also differences between these two ways of knowing. Descriptions of TEK vary, but most include: 1) detailed systematic observations of the environment of a specific place through direct interaction; 2) an active process that makes use of new information and often includes elements of knowledge handed down through generations (Berkes et al. 2000; Mauro & Hardison 2000; Ramnath 2014; UNEP 2008), and; 3) a holistic understanding of ecosystems and interactions among ecosystems and human socio-economic systems (Philip 2001). Fienup-Riordan and Carmack (2011) characterize it as tacit knowledge embodied in life experiences and reproduced in everyday behavior and speech. Indigenous knowledge (IK), while encompassing cumulative place-based observations of natural phenomena that includes humans and non-human others, additionally integrates and acknowledges humans as part of the natural world and its processes (Pierotti et al. 2000). In TEK and IK, cues are rich, and observations are holistic.

Fienup-Riordan and Carmack (2011) define Western science as: 1) investigations based on the scientific method; 2) a body of techniques for formulating and testing hypotheses, and; 3) based on systematic observation, measurement and experiment. Scientists typically view Western science as analytical, reductionist, positivist, objective, and quantitative (Berkes et al. 2000; Fienup- Riordan & Carmack 2011; Mauro & Hardison 2000; Ramnath 2014). Western scientists typically simplify and control their experiments, sometimes studying a single isolated parameter, and purposely attempt to isolate themselves from context (Fienup-Riordan & Carmack 2011). Western science is able to examine phenomena at larger scales, but often during shorter increments of time. In the Arctic, observations occur largely during the summer field season and projects are often five years or less (Eicken & Lee 2013). In this paper, following Alexander et al. (2011), we define science as “a set of statistically analyzed data or instrumental records . . . that can be empirically measured and that demonstrate acceptable levels of reliability and validity” (p. 477). We refer to the instrumented data we use in this paper as Western Science Instrument-Derived Data (WSIDD). And the place-based local observations are referred to as community-based observations. We also note that while some community-based observations may overlap with TEK or IK, for particular observers, but they are not synonymous.

Community-based observations of change in the Arctic

Natural selection has not shaped our perceptions to be an accurate representation of objective reality, but has shaped our perceptions to be species-specific guide to behaviors that we need to survive and reproduce (Hoffman 2009). Perceptions are a complex interaction among the organism, the environment, and the social context in which an organism is found (Hoffman 2009; Hoffman & Prakash 2014). We are not capable of perceiving or observing everything that surrounds us, and, similar to optimal foraging strategy, to do so would require too much energy and time for us to observe and process. Hence, natural selection has shaped our perception to attend to that which most highly relates to our survival and ability to reproduce (Hoffman et al. 2015).

Additionally, environmental conditions are an adaptive system with great variability and can be difficult to quantify (Levin 1998). We have assumed that observers who rely on the land and sea for their food may be particularly adept at observing and reporting complex ecological systems. Few studies have compared community-based observations to instrumented data. An understanding of under what circumstances community-based observations are most accurate would be beneficial in the continued use of CBONS. "The purpose of such comparison is not to 'validate' one set of observations in terms of the other. Rather, it is to combine them while taking advantage of their differences . . . ." (Huntington et al. 2004, p. 18).

Studies that have examined whether community-based observations and instrumented data have converged include: Prno et al. (2011) who found convergence between scientific literature related to trends in temperature and precipitation and observations of changes to sea ice by residents of Kugluktuk, Canada. Fienup-Riordan and Carmack (2011) documented a correspondence between Western science studies and TEK understanding of the response of sea ice to ocean waves, swells and tides, the formation of shore ice and ice piles and changes in timing of break up and freeze up in villages along the west coast of Alaska.

Inuit elders in the Foxe Basin, Canada characterized the summer ice conditions and late freeze up of 2006 as being "unprecedented in living memory" and instrumented records supported both observations (Ford et al. 2008). Weatherhead et al. (2010) examined the Clyde River/Baker Lake region of Nunavat, Canada. A 50-year record of hourly temperature data confirmed local residents' observations that weather was less predictable due to an increase in variability.

Herman-Mercer et al. (2011) compared local observations of weather, river conditions, flora and fauna in two small villages on the lower Yukon River, Alaska: St. Mary's and Pitka's Point and Huntington et al. (2004) compared local observations of plants, lichens, and insects across northern Canada and northwest Alaska found correspondence in most observations. In both of these studies, TEK observations occurred at local scales while scientific observations occurred at regional scales, primarily across the Arctic. Ambrose et al. (2012) found expert fishers in Kotzebue Alaska to be more sensitive to environmental change as compared to elders and expert hunters. This study suggests that TEK knowledge may be domain-specific.

Community-based observations, and TEK specifically, have been compared to fuzzy logic, which employs heuristic rules. Fuzzy logic enables people to successfully navigate ecological complexity (Berkes & Berkes 2009) and provides flexibility for people to adapt and thrive in natural environments (Turnbull 2000). Expert fishers have been shown to use heuristic rules to process ecological knowledge (weather, fish behavior, 'folk oceanography', etc.) to make decisions related to fishing (Grant & Berkes 2007). Nonetheless, there is likely to be some uncertainty present as understanding ecosystems is a complex process and observations of the environment are seen through the filter of human perception. While these studies make specific reference to TEK we argue that they are not unique to Indigenous populations but apply more broadly to place-based local knowledge or community-based observations generically.

Other research has found a lack of correspondence between community-based observations and instruments. Gearheard et al. compared wind data with observations at Clyde River, Nunavut, Canada and found little correspondence between observations and instrumented data (2010). Alessa et al. (2007) found differences between perceptions of change in water quality and quantity of younger observers compared to middle-aged and older observers in western Alaska, finding that accuracy increased with age. Ambrose et al. (2014) found that expert fishers were more highly attuned to environmental changes in marine species than were elders or expert hunters.

METHODS

Social Data: Community-based data were collected as part of the Bering Sea Sub-Network (BSSN) project funded by the National Science Foundation. Community Research Assistants (CRAs) were hired from within the community to conduct interviews. All interviewers were trained and provided with guidelines on interviewing. Consent was obtained from all participants in the study. The same questions were asked at all locales, albeit in languages appropriate to the survey respondents: English, Russian, Yup'ik or Siberian Yupik. Interviewers were different in each village and larger villages had two interviewers. Community experts and project personnel created a list identifying knowledgeable elders and high harvesters, defined as those who frequently harvest in their community, and had done so for 15 or more years. Directed sampling was used with the goal of capturing a majority of high harvesters and knowledgeable elders.

Survey questions assessed observed change in a variety of environmental variables including: timing of freeze-up and break-up, ice conditions, wind direction, wind velocity, air temperature, water temperature (sea, and river or lake), frequency and intensity of storms, snow conditions, rain and changes in vegetation. Surveys included multiple-choice and open-ended questions. For each environmental condition, the respondent was first asked the yes, no or don't know question, "Have you observed changes in (environmental condition) in the past 15 years or longer?" Next they were asked what changes they had observed in that time period and the direction of change specific to each season. They were then asked, "When did you first notice these changes?"

Quantitative data from the surveys in the form of yes, no, or don't know responses to the question whether participants had observed change were analyzed using SPSS 22 and 23. We aggregated spring and summer seasons and fall and winter seasons in questions about temperature change as studies predict that fall/winter temperatures will increase more than summer temperatures in the northern latitudes (Kirtman et al., 2013, p. 984). We defined spring/summer as April through August and fall/winter as September through March. For the qualitative data indicating direction of change, emergent coding in NVivo was used to categorically organize observational data.

Biophysical data: Based on papers assessing the reliability of WSIDD gauged data in Alaska written by Kane & Stuefer (2015) and by Bauret & Stuefer (2013) we eliminated instrumented precipitation records as being insufficiently reliable for comparison to human perceptions.

Instrumented data for wind had a significant percentage of missing values for all communities and it was determined that this data was not sufficiently reliable as well. We analyzed missing values in the air temperature datasets; and examined the scientific literature for studies on environmental changes in the area in which the villages are located. We assessed satellite imagery to determine whether sufficient data existed to test vegetation change in the villages. We determined that sufficiently robust air temperature data existed for Nikolskoye, Tymlat, Togiak, and Sand Point; scientific studies of ice break up and freeze up for Savoonga and Gambell; and satellite images of vegetation change for all villages except St. George.

Air Temperature: WSIDD air temperature data were downloaded from the National Oceanic and Atmospheric Administration's (NOAA) National Climate Data Center (NCDC). Monthly or daily datasets were selected based on which was more complete (Lawrimore et al. 2011). The datasets were analyzed for missing values. The villages included in the analysis (because 90% or greater of the data was available) were: Nikolskoye, Tymlat, Togiak, and Sand Point. As with the social data, we analyzed spring/summer and fall/winter temperature data separately, defining spring/summer as April through August and fall/winter as September through March.

Trend analysis for fall/winter and spring/summer months was conducted using Minitab 17. The average temperature was calculated for the time periods available for each village. A fitted time series was determined using linear regression analysis; specifically the sum of the squared vertical distances from all observations was minimized to the fitted line. We calculated a 95% confidence interval for the slope of the line of best fit. Of particular importance, is the sign of the slope of the trend line from which we could conclude with 95% certainty that temperatures had increased (positive confidence interval) or decreased (negative confidence interval).

Because trend analysis does not indicate whether a statistically significant change has occurred, we used a two sample t-test. The purpose of the two-sample t-test, also known as the (non-pooled) independent samples t-test, is to perform a hypothesis test to compare two population means. Under the assumption that the two observed datasets are independent simple random samples from two normal populations, we tested the null hypothesis that the means are equal versus the alternative hypothesis that the means are not equal, using a fixed significance level of .05. The two-sample t-test is known to be robust to moderate violations of the normality assumption.

The time periods used to compare means for each village were determined by calculating the median year in which respondents said that they had started noticing changes in temperature (hereafter the median year). The time period from the start of data availability to the end of the year immediately preceding the median year was compared to the time period from the beginning of the median year to the end of the time that the social survey was administered in the relevant village. The comparison periods for each village are as follows: Nikolskoye (January 1979 through December 2003, and January 2004 through May 31, 2010); Tymlat (January 1981 through December 2005, and January 2006 through August 31, 2010); Togiak (July 1992 through December 2007, and January 2008 through December 31, 2012); and Sand Point (August 1983 through December 2007, and January 2008 through August 31, 2012).

Timing of ice break up and freeze up: WSIDD assessments of ice break up and freeze up times have been conducted for sea-ice surrounding St. Lawrence Island, on which the villages of Gambell and Savoonga are located. A study was conducted by Grebmeier et al. (2006) on the timing of sea ice break-up based on air temperature records. In 2012, Grebmeier examined sea ice retreat in the Chukchi Sea and Bering Sea to just south of St. Lawrence Island. Shimada et al. (2006) studied sea surface temperature and its effect on ice formation in the Chukchi and Beaufort Seas which surround St. Lawrence Island. The heat flux through the Bering Strait has steadily increased from 2001 to 2007 (Woodgate et al. 2010). These studies were used to assess community-based observations of sea ice change.

Vegetation change: We measured regional vegetation change using MODIS satellite imagery for each of the study communities. Specifically, we used the MODIS 16-day Normalized Difference Vegetation Index (NDVI) composite available through Google Earth Engine (earthengine.google.com). NDVI is regularly used to measure vegetation change and has proven particularly effective in the Arctic and subarctic (Jia et al. 2003, Stow et al. 2003, Verbyla 2008, Pattison et al. 2015). The 16-day composite is especially useful in northern coastal communities where cloud cover often reduces the utility of individual image scenes. Access to Google Earth Engine allowed us to use top of atmosphere (TOC) corrected images (Chander et al. 2009), and facilitated rapid assessment across the different study locations using the entire MODIS archive.

Average NDVI was calculated for a 50km buffer around each village location to represent the general community area of use. Buffers were then modified to remove any ocean so as to not bias the NDVI values. Average NDVI was calculated beginning in 2000 (first year of MODIS) until the survey year for each village using the modified buffers. On average, there were 283 composites available for each village, with occasional gaps during winter months.

Annual NDVI trends were analyzed using Seasonal Decomposition of Time Series by Loess (STL; Cleveland et al. 1990). STL works by removing seasonality to assess long-term trends in NDVI.

RESULTS

Air Temperature

Nikolskoye

Trend analysis indicates that there has been an increase in temperatures in Nikolskoye over the temperature record from 1979 to 2010 for both the spring/summer and fall/winter time periods. Compared to the mean temperature from 1979 through 2003, mean temperature from 2004 to 2010 was about 0.5 °C higher in fall/winter and about 0.9 °C higher in spring/summer. About equal numbers of survey participants observed that it was warmer and that it was colder in the winter and in the summer. Ten respondents indicated that it was colder in fall, whereas 16 said it was warmer. Only spring clearly had consensus, two said spring was warmer and 23 said it was colder. The t test indicated that the increases were not statistically significant, despite an almost 1 °C increase in spring/summer – an indication that air temperature is highly variable in this region.

Tymlat

Similarly, trend analysis indicates that there has been an increase in WSIDD temperatures in Tymlat, over the time period 1981 to 2010, for both the spring/summer and fall/winter time periods. Comparing the two time periods, there was a 0.9 C increase for fall/winter and 0.5 °C for spring/summer. Of 51 respondents, only 22 indicated that there had been a change in temperature. Of the 22 who responded, 7 said that winter was warmer. Responses to questions about temperature change and direction were low. No other question garnered more than four responses. The t test indicated that the increases were not statistically significant, again an indication of variability when considering the overall increase.

Togiak

In Togiak, trend analysis indicated there was a WSIDD temperature decrease in fall/winter of 1.5 °C from 1992 to 2012. Fifty-two percent of respondents in Togiak, however, reported that fall/winter was warmer and 18.6% reported these seasons as colder. In spring/summer, there was a decrease in temperature of about 0.5°C. Smaller numbers of survey participants responded to the question about spring/summer and the largest percentage (11%) indicated that summer was colder. Both trends in temperature were significant in t tests.

Sand Point

Sand Point was colder in both fall/winter (about 0.9°C decrease) and in spring/summer (about a 0.6°C decrease) over the period from 1983 through 2012 based on WSIDD records. Fifty-nine percent of respondents answered the question about air temperature change direction and of those, 36% indicated that both seasons were colder while 23% said both seasons were warmer. T tests for both seasons were significant. See Table 1 below.

Village	Time periods for which means were compared spring/summer	Mean WSIDD change in temp spring/ summer	Percent of participants noting trend shown by instrumented data	Time periods for which means were compared fall/winter	Mean WSIDD change in temp fall/winter	Percent of participants noting trend shown by instrumented data
Nikolskoye	1979-2003 2004-2009	+0.9°C	27%	1979-2003 2003-2010	+0.5°C	47%
Tymlat	1981-2005 2006-2010	+0.5°C	10%	1981-2005 2005-2010	+0.9°C	14%
Togiak	1993-2007 2008-2012	**-0.5°C***	11%	1992-2007 2007-2012	**-1.5°C****	19%
Sand Point	1983-2007 2008-2012	**-0.6°C****	36%	1983-2007 2007-2012	**-0.9°C****	36%

Table 1: Summary of mean change in temperatures, time-periods that means were compared and percent of study participants whose observations were consistent with instrumented data. Significant relationships are in bold. The levels of significance are: *$p < 0.05$, **$p < 0.01$.

Ice Break Up and Freeze Up (Gambell/Savoonga)

Fifty-two percent of Gambell survey participants indicated that ice freeze up was later, and 61% indicated that ice break up was earlier. In Savoonga 52% indicated that ice freeze up was later and 50% indicated that break up was earlier. Grebmeier et al. (2006) calculated the timing of sea ice break-up as occurring 3 weeks earlier just south of St. Lawrence Island based on WSIDD air temperature records, although this was calculated during a warm period in the Bering Sea (2001-2005) which was followed by a cold period (2007-2010) (Stabeno et al. 2012). Just north of the Bering Strait, the Chukchi Sea has consistently had earlier spring sea ice retreat (Grebmeier 2012). Shimada et al. (2006) demonstrated that WSIDD sea surface temperature around St. Lawrence Island increased from 1978-2004, which affected ice formation in the Chukchi and Beaufort Seas surrounding St. Lawrence Island, accelerating break up time. The heat flux through the Bering Strait has steadily increased from 2001 to 2007 (Woodgate et al. 2010). The observations of the majority of St. Lawrence Island residents that break up is occurring earlier and freeze up later support these WSIDD records.

Changes in Vegetation: A majority of survey participants across all villages except Togiak reported that there had not been a change in vegetation. Sixty-nine percent of participants in Gambell, 83% in Savoonga, 72% in Kanchalan, 62% in Nikolskoye, 80% in Tymlat, and 69% of participants in Sand Point answered no to the question whether there had been changes to vegetation. In Togiak, 42% answered that there had been no changes, 41% answered that there had been changes. Statistical analysis of vegetation change shows that there is considerable seasonal and inter-annual variability in NDVI (Figure 2). Decomposing the time-series into seasonal and trend components reveals no long-term trends in NDVI for any location. Figure 2 shows NDVI trends for each of the villages surveyed using the MODIS 16-day composite. To further quantify this result, linear regression models were fit to each time series, with no statistically significant trends detected.

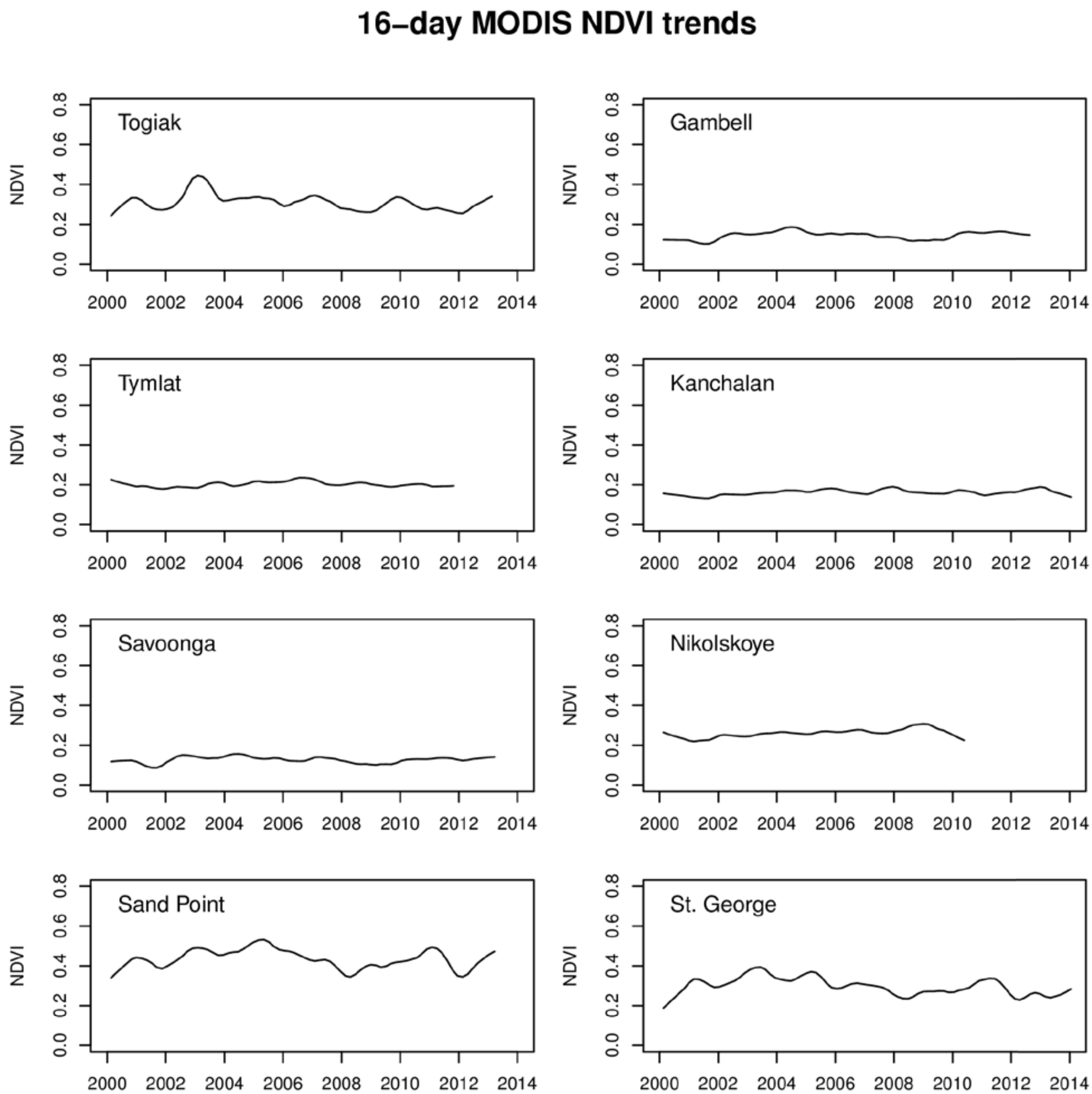

Figure 2: NDVI trends for each of the villages surveyed using the MODIS 16-day composite. Trend analysis was ended on the last survey date (Appendix 1).

DISCUSSION

Air temperature observations

The majority of survey responses in all communities did not correspond closely with WSIDD air temperature trends in either spring/summer or fall/winter. The closest to a majority of corresponding observations occurred in Nikolskoye in which 47% of respondents reported increasingly warm fall/winters in that area (Table 1). It is interesting to note that, with the exception of the relatively larger decrease in spring/summer temperatures in Togiak (~-1.5°C), the mean temperature increases in Nikolskoye and Tymlat were very similar, as were the mean temperature decreases in Togiak and Sand Point. Only Togiak and Sand Point, however, had statistically significant change, indicating that temperatures in Nikolskoye and Tymlat had greater variability.

Despite the overall mean change in temperature in Togiak in the fall/winter of -1.5 °C, the change was not perceived and this relatively large change was not statistically significant because of variability in temperatures. Fifty-seven percent of Togiak residents stated that fall/winter temperatures were warmer, 19% stated it was colder. This suggests that variability may impact community perceptions of changes in air temperature when compared to WSIDD. This is supported by prior research in which respondents of northern communities in Nunavat, Canada reported that weather was less predictable, and this observation was statistically supported by analyzing the increase in variability of the weather in that area based on WSIDD (Weatherhead et al. 2010). At 60˚ North latitude, the rounded latitude of the communities included in this study, mean annual variation in temperature is 30˚C /54˚F. Mean annual variation in temperature increases with increased latitude. (Brigham Young University n.d.). In addition to annual variation, there is pronounced temperature variation from season to season.

Humans may be poor observers of temperature overall when compared to WSIDD. Air temperature and trends in air temperature over time is arguably a much more important environmental variable for people living in lower latitude urban areas than in upper latitude rural areas. Deschenes and Moretti (2007) studied deaths from heat and cold waves and found "mortality rates are significantly higher on both cold and hot weather days, but that the excess mortality on hot days is substantially larger (e.g. 3-6 times larger) than on cold days." p. 13.

The Urban Heat Island effect accelerates temperature changes in cities (Arnfield 2003; Lowry 1967; Taha 1997; Voogt 2002). In large cities such as Chicago (Semenza et al. 1996), Cincinnati (CDC 2000), Philadelphia (Mirchandani et al. 1996), and Paris, France (Vandentorren et al. 2004), among many others, thousands of deaths each year are caused by summer heat waves. The Maricopa County Department of Public Health (in which Phoenix is located) concluded that heat or heat exposure was a direct or contributing cause of 215 deaths from 2005 to 2007 (MCDPH 2008). In a study conducted in metropolitan Phoenix Arizona in 2006, a year after an unprecedented heat wave in 2005, researchers analyzed the correspondence between a climate model that had shown accurate results on finer scales, and hence the ability to assess microclimates, and people's perceptions of changes to regional and neighborhood air temperatures. Tests indicated only "a modest positive association between daily average, high, and low neighborhood temperatures and respondents' aggregated perceptions of change in regional temperatures over time (r=0.26 to 0.33)." Statistics were stronger, but still statistically modest, for aggregated perceptions of temperature at finer scales of neighborhood relative to other neighborhoods (r=0.47 to 0.50). The correlation at the neighborhood level was statistically significant, although below r=0.50 (Rudell et al. 2012, p. 596).

Given the direct safety concerns from higher temperatures in Phoenix, it is surprising that perception is not more accurate at both neighborhood and regional scales. Variation in temperatures is not as significant a factor in Phoenix, which is located at 33˚ North latitude where mean annual temperature variation is 13˚C/23˚F (at 30˚ North latitude) (Brigham Young

University n.d.). Despite less variation, perceptions even a year following the heat wave were poor. Another factor impacting perceptions might be technological protection from the elements (Technologically-induced environmental distancing) (Alessa et al. 2010) in the form of air-conditioned houses and vehicles, which mute the extremes of environmental temperatures.

Why might perceptions not track more closely to instrumented air temperature data in the communities in this study? First, air temperature change that has occurred over the time periods used in this study is not a direct threat to survival or reproduction. That is, temperature increases and decreases have not reached extremes that have caused deaths. Daily air temperature certainly has a direct effect on survival when making decisions of what clothing to wear, but when daily temperatures can vary by 15 to 20˚C, attire must always be adaptable.

Indirect effects of increases in air temperature certainly impact survival in these communities, including making travel on ice more risky, and access to food resources more difficult. It is these more direct effects of changes in ice and snow cover that affect survival and people in northern regions perceive these changes more accurately. Another explanation may be that people more accurately perceive microclimates where they live and hunt. Placement of gauges in northern communities is sparse and related to ease of access. Neither gauges, nor climate models, accurately account for microclimates in northern regions, which might explain a great deal of the difference between perception and instrumented data. We also did not analyze perceptions at finer time scales, as the study allowed participants to decide at what time scales change had occurred. Such an analysis might also decrease the difference between the perceived and instrumented change. Although one would anticipate that because of increased time on the land of many of the study participants, the effect of having a warm house to retreat to would have a lower impact on perception of air temperature change than in large cities, technology-induced distancing may have affected perception in these communities as well.

Ice break up and freeze up

Observations of changes in sea ice are interesting because, although general trends are well-documented (thinning, decrease in extent, change in timing of freeze and thaw), changes vary regionally with some areas not experiencing change (Meier et al. 2011) even within the Bering Sea (Stabeno et al. 2012). An effort was made to verify observations with literature as close as possible to the local scale. As these are large scale changes, and Savoonga is only 63 km from Gambell, both villages were considered together. In this case, a relatively large body of scientific research conducted in the area of St. Lawrence Island supported the observations that break up was occurring earlier and freeze up later in these villages. Ice break up and freeze up have been confirmed by a number of other studies as being phenomena that are accurately observed (Prno et al. 2011; Fienup-Riordan & Carmack 2011; Ford et al. 2008).

The timing of ice events significant to survival by respondents was accurately perceived. These changes directly impact the ability of people living in these communities to travel safely and to gather food. Cognitive neuroscience suggests that natural selection has not shaped our perceptions to be an accurate representation of objective reality, but has shaped our perceptions to be species-specific guide to behaviors that we need to survive and reproduce (Hoffman 2009; Hoffman & Prakash 2014). Studies also suggest that people are more likely to perceive risks after catastrophic events than changes that are slowly evolving (Rudell et al. 2012). As noted above, changes in ice conditions have resulted in increased deaths from travel on ice, a catastrophic event. More accurate perceptions of ice changes, which have a direct effect on survival, are consistent with the theories of Hoffman and Prakash.

Vegetation changes

Analysis of annual NDVI suggests that there has been no significant vegetation change in any village. Respondents from all of the villages, except Togiak, correctly reported that no vegetation changes had occurred. Togiak respondents were equally split in their opinions that vegetation had and had not changed. As shown in graph 1 and graph 2 below, maximum NDVI over time is highly variable. Although variability could impair the accurate observation of vegetation change, as it appears to have in air temperature change, vegetation change is much less variable than air temperature change and more villages accurately observed that vegetation had not significantly changed.

As well, changes to vegetation relate more closely to ability to survive in these communities as all communities gather greens for food. If greens had increased, which would be represented in NDVI, it would make sense that these communities would perceive this since it would likely increase their access to a food source.

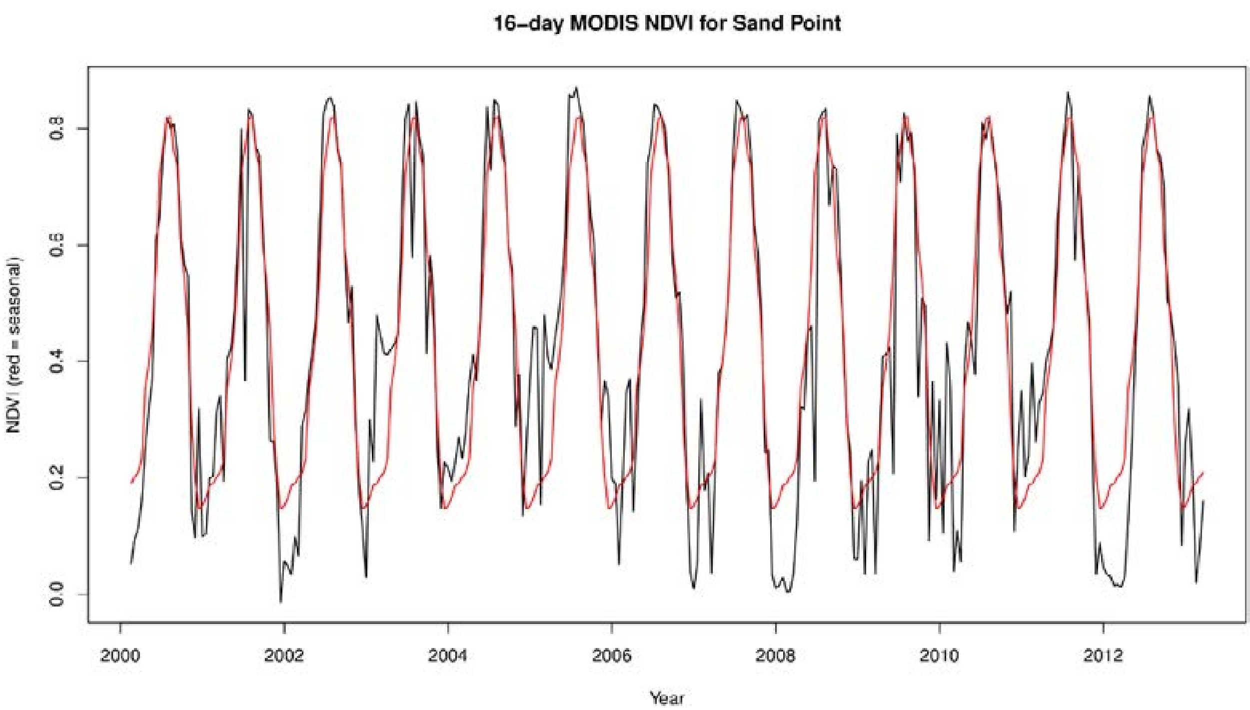

Figure 3: Plot of annual variation in NDVI for Sand Point, Alaska. The red line indicates expected seasonal NDVI values (using the STL method), while the black line indicates observed NDVI values. This shows both the annual magnitude of NDVI change as well as the lack of change in green-up or length of season over the time period.

CONCLUSION:
Research into how and under what circumstances people's perceptions of the environmental are veridical to WSIDD environmental conditions is sparse. Cognitive neuroscientists have suggested that perception that closely tracks actual conditions does not increase adaptive capacity, a surprising result (Hoffman 2009; Hoffman & Prakash 2014). This may be partly explained in terms of the amount of information available from the environment and the amount of energy and time needed to process this information. Perception that is attuned to increasing our fitness to survive and reproduce will be selected (Hoffman 2009; Hoffman & Prakash 2014). Perceptions that reduce the amount of information we process to that which is most relevant to the particular environment, social conditions and circumstances of the observer are those that will most likely increase our survival. Our perceptions are likely place-based and function as complex adaptive systems.

Researchers have compared the techniques used by local place-based observers to characterize their environment as "fuzzy logic" (Berkes & Berkes 2009). Other research suggests that people do not limit their observations to single variables, but combine them to discern patterns in the environment (Berkes et al. 2007). Asking survey participants whether temperature, rain or wind direction had increased may have imposed Western science ways of observing on an Indigenous system and may have assured inaccurate responses, because those questions were not related to other variables in a meaningful way that relates to increased survival or ability to reproduce. Berkes et al. (2007) suggested that questions related to topics of safety, access to resources, species health and availability, and predictability result in keener observations. These suggestions are consistent with research in cognitive neuroscience and are supported by this study. Ambrose and colleagues (2014) found the following five questions to be most predictive of climate change knowledge in their study: temperature of water compared to 10 years ago, arrival of salmon, migration of trout, amount of flounders caught in nets, and water temperature increase resulting in an increase in crabs; all phenomena concerned with species health and availability, and access to subsistence resources.

Importantly, this study suggests that large variability in environmental conditions reduces the correspondence of community-based observations, this is true of even people who are, arguably, most attuned to environmental change, compared to WSIDD measurements of change. Climate scientists predict more variable climate, which may create situations where change is very difficult to predict. Other studies have supported the observations of people living in northern latitudes that climate is becoming less predictable.

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APPENDIX

Table 2. Some demographic and survey information for the Environment Survey

Village	Population	Number of	Response	%	Average	Years	Survey
		Respondents	Rate	Male	Age	hunting and/or fishing	administered
Nikolskoye	~800	85	73%	88%	52	31	03/2010 – 05/2010
Tymlat	~500	51	33%	80%	51	30	06/2010 – 10/2011
Kanchalan		50			51		05/2010-06/2010
Gambell	681	77	37%	86%	52	38	01/2011-8/2012
Sand Point	976	70	65%	84%	52	35	01/2010 – 03/2013
Savoonga	671	52	35%	87%	55	40	5/2012 – 3/2013
Togiak	821	151	71%	51%	47	30	01/2010 – 02/2013
St. George		9			57		07/2011-07/2012

Engaging rural communities in permafrost and climate monitoring in the Upper Kuskokwim region, interior Alaska

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Alaska's land, water, plants, wildlife, and seasons are undergoing a great upheaval, and its people, especially the tribal communities living in remote villages are directly and severely impacted by these widespread environmental changes. These environmental changes are not only widespread but also often so rapid that we cannot possibly have enough scientist and professional on the ground to detect and predict these changes before their effects are obvious. Especially environmental changes occurring in and around the remote communities in Alaska are directly affecting the tribal livelihood, recreation and subsistence practices and thus have the most impact on the socio-economic conditions of these communities. In order to detect, monitor, and forecast these environmental changes to better prepare the communities to respond and adapt we need to engage the community members in scientific monitoring and assessment process. We could potentially build adaptive and resilient communities by observing and monitoring processes and indicators that the communities want to monitor.

With the above strategy in mind, the Geophysical Institute Permafrost Laboratory at University of Alaska Fairbanks and Telida Village Council secured funding from the National Science Foundation in September 2015 to build community capacity to monitor permafrost and related environmental changes in the vicinity of the Telida village in the Upper Kuskokwim region of interior Alaska. The overarching goal of this project is to help the tribal communities take the lead in assessing and responding to the environmental changes that are coming with warming climate and thawing permafrost. Permafrost being a subsurface feature, the best way to assess the permafrost condition is by scientific observation and instrumentation. The project will help build the tribal capacity to monitor changes in local climate and permafrost by providing the Tribes the scientific knowledge and skills necessary to acquire, analyze, and interpret scientific data through training and education. We will use the local knowledge on permafrost and landscape change to identify key sites for detailed field observations and instrumentations. In consultation with the participating community members, the project will establish local climate and permafrost observation system, map land cover and permafrost in the Upper Kuskokwim region. It will also develop a geo-hazard map for the region to facilitate safe subsistence and recreational practices and land use.

The community is aware that in their region permafrost is discontinuous i.e. near-surface permafrost is generally present in lowlands where black spruce and sphagnum grow in peat that is a foot or thicker and found sporadically in areas of birch, aspen, willow and cottonwood stands. Permafrost is thawing out and affecting their means of travel and subsistence food resources. The community wants to have a better and scientific understanding of relationship between permafrost degradation and impact on their physical environment and tribal way of life. The members of the community involved in this project, Charlene Dubay and Teresa Hanson, are convinced that the best way to assess and respond to environmental changes is by building community capacity, getting involved in research, and incorporating scientific data and knowledge in planning for the future.

The permafrost related environmental impacts that the community is aware of are a) drying of lakes which affect their fishing and trapping, b) lower water level in Rivers which affect their main mode of transportation in summer, c) appearance of sinkholes that pose threat to the safety of the community members and their properties, and d) eruption of a sand dune in the middle of the Telida village air strip.

The community has not done anything significant to deal with permafrost changes yet, but it wants to take necessary steps to improve their understanding of climate change and permafrost thaw, and to minimize the impact of permafrost degradation on their environment, subsistence food resource, and transportation. Using scientific data and knowledge, the community members want to develop the best practices for assessing and responding to the changes, and better prepare for the changes coming with warming climate and thawing permafrost.

In summary, the project will offer the traditionally-underserved tribal communities of the Upper Kuskokwim region and the Tribal Council an opportunity to engage in climate research. It will provide them the motivation, resources, climate science knowledge and skills to study the impact of climate change on their tribal way of life and environment. The data, knowledge, and skills gained through this project will benefit the tribal communities in adaptive management of subsistence resources, implementation of safe land use practices, and planning for the future. The scientific community will also benefit hugely by having an improved understanding of permafrost dynamics, access to field data and maps from this understudied remote part of Alaska. The lessons that will be learned from this project will contribute to the development of best practices and standard in building successful community based permafrost monitoring programs. In addition, the project will provide outreach and workshops on climate change to the community members using examples from their own communities to advance their climate science knowledge and encourage them to use scientific data and knowledge to plan for the future.

Arctic Indigenous Observing Strategies

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Abstract

The recently-published 2014 IPCC WG2 "Polar Regions" chapter has underscored the importance of addressing the issues of the indigenous communities in the Arctic as well as strengthening their voice and role in the planning and implementation of research to understand the environmental changes and impacts taking place across the north as well as practical and timely solutions. (Larsen et al, 2014). This paper summarizes some recent recommendations for enhancing the availability and use of local, indigenous, and community-based knowledge as well as scientific research data among all communities.

> *"…Indigenous, isolated, and rural populations are especially vulnerable to climate change due to a strong dependence on the environment for food, culture and way of life; their political and economic marginalization; existing social, health, poverty disparities; as well as their frequent close proximity to exposed locations along ocean, lake or river shorelines…." (Larsen et al, 2014)*

Although indigenous communities are facing climate, development, and other changes, which are impacting community infrastructure, health, water supplies, food, and safety on a daily basis, they have had limited participation in the scientific studies associated with these changes. This is due in part to the indigenous emphasis on relationships among biophysical, ecological, and cultural components versus the western science emphasis on specific facts. (Cochran et al 2013) A number of multi-faceted approaches have been suggested to help broaden indigenous participation in climate change research to strengthen the voice of the communities. This paper summarizes some recent recommendations for enhancing the availability and use of local, indigenous, and community-based knowledge as well as scientific research data among all communities.

A recent study by Cochran et al (2013) in Alaska outlines a multi-pronged approach to ways that indigenous peoples can contribute more effectively to understanding and adapting to climate change – as follows:

1. *"Engage communities in designing climate-change solutions*
2. *Create an environment of mutual respect for multiple ways of knowing*
3. *Directly assist communities in achieving their adaptation goals*

4. *Promote partnerships that foster effective climate solutions from both western and indigenous perspectives*
5. *Foster regional and international networking to share climate solutions"*

In a presentation on the "*Consequences of Changes Across the Arctic: Implications for Arctic Indigenous Peoples*" in 2011, a list of potential solutions and strategies for future adaptations via "Indigenuity" (Indigenuity = Indigenous + Ingenuity - A term coined by Dr. Dan Wildcat of Haskell Indian Nations University) was given which outlined some of the key strategies for creating resilience in the Sami indigenous reindeer herding community discussed among members of a research team – which can be applied to a more general indigenous community observing approach. (Maynard 2011) They were as follows:

1. *Utilize all best available Indigenous and scientific data and observations for decision-making and predictions: Indigenous knowledge, science, technologies, weather, etc.*
   a. *Collaborate & co-produce*
   b. *Create strong partnerships*
2. *Utilize a local observations & monitoring network (e.g., the International Centre for Reindeer Husbandry) to ensure strong input of indigenous knowledge for decision-making & predictions*
3. *Create assessments & adaptation strategies to address impacts of climate change, development, pollution, & loss/changes (e.g., in pasturelands on indigenous reindeer herder communities)*
4. *Expand outreach, education, capacity-building and information-sharing among all stakeholders*
5. *Establish agreements between indigenous communities and industries and governments to ensure they can co-exist in changing climates (e.g., adaptive access to historical pasturelands and migration routes)*
6. *Create mechanisms for clear and on-going communications between indigenous communities and the oil and gas industry and governments for co-managing land use*
7. *Ensure that Indigenous knowledge and peoples are included in decision-making which impacts the herding community*
8. *Ensure that industry, governments & reindeer herders work together to help preserve language, culture and well-being of Indigenous peoples*
   (Maynard, 2011)

Finally, when addressing the most effective ways of "Interfacing Traditional Knowledge, Community-Based Monitoring and Scientific Methods for Sustained Arctic Monitoring", it is important to include the conclusions from the NRC 2009 report on *Informing Decisions in a Changing Climate*. Their key considerations in the design of observations and data system to support decision-making support are as follows:

1. *Begin with user needs*. Decision support activities should be driven by users' needs, not by scientific research priorities.
2. *Give priority to processes over products*. To get the right products, start with the right process.
3. *Link information producers and users*: Decision support systems require networks, and institutions linking information producers and users
4. *Build connections across disciplines and organizations*.
5. *Seek institutional stability*: Decision support systems need stable support. (i.e., long term financial commitments to maintain continuity of data and gap free data)
6. *Design for learning*. (Learning from experience with constant dating and redesign to assure currency and relevance)

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Community Paper for the 2016 Arctic Observing Summit

Theme 6: Interfacing Traditional Knowledge, Community-based Monitoring and Scientific Methods for sustained Arctic Observations

October 18, 2015

Our Beluga, Fish and Environment are Changing: Traditional Knowledge study on food resources on Kendall Island in the Inuvialuit Settlement Region

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Summary/Abstract

Inuvialuit people are making observations of climate change that may be affecting the health of beluga and fish at traditional harvest camp on Kendall Island, Inuvialuit Settlement Region, NT, Canada. In response, the Inuvik Hunters and Trappers Committee led a community based research project with Elders and youth to document the types of changes being observed in the Western Arctic coast through traditional knowledge interviews and experiences on the land. Outcomes from interviews highlighted eight themes that ranged from the importance of respecting the land to the value of beluga harvest and fishing to the culture and well-being of the Inuvialuit.

Introduction

At the global scale the Arctic has experienced warming at twice the global average (IPCC 2013) with rates of sea ice loss faster than previously predicted (Stroeve et al., 2012). At the local and regional scale, communities are noting changes in the environment and need to adapt to continue their subsistence-based livelihoods (Pearce et al., 2006). The Inuvialuit settled their land claim in the western Canadian Arctic in 1984; today, the Inuvialuit reside in six communities and co-manage their natural resources (IFA 1984). Beluga whales (*Delphinapterus leucas*) have long been an important component of Inuvialuit subsistence and are central to their cultural well-being (McGhee 1988). Despite the settlement of permanent communities in the Mackenzie Delta (e.g. Inuvik and Aklavik), many Inuvialuit continue to harvest beluga whales travel to summer camps along the coast to both hunt and fish (Harwood and Smith, 2002). Billy Day described where people went historically to harvest beluga whaling; these locations are still utilized as whaling camps today.

> "There are a number of places that people would go for whaling each summer: East Whitefish Station (Nalguriak), Kendall Island (Ukeevik), West Whitefish (Neakonnak), and Shingle Point (Tapkak). The people from Tuktoyaktuk would also go whaling right from home." (Billy Day, Tusaayaksat, p.30).

Community members, harvesters, elders and youth have observed changes in the physical environment, fish and beluga whales that they hunt at these camps. Questions and concerns have been raised regarding the viability of long term harvesting in the area, access to these areas, and how to properly monitor the changes in order to determine a means to adapt to ongoing and future changes. Thus, a community-based project was proposed by the Inuvik Hunters and Trappers Committee (IHTC) to respond to harvester and community questions and concerns about the changing environment. This project specifically addressed changes in beluga whales and fish being observed at the whaling camps, as these changes were affecting the livelihoods of the Inuvialuit. The IHTC identified the need to collect traditional and local ecological knowledge (TEK/LEK) of the area and species. A pilot project was launched by the IHTC to collect beluga whaling and fishing TEK at Kendall Island in July 2012. This project was organized to have Inuvialuit youth collect TEK from Elders and seasoned hunters and trappers through a series of interviews.

Approach

The project was led by the community; the two project leads and coordinator were residents of Inuvik and they created a team made up of four Elders, three youth and one translator to conduct TEK interviews on Kendall Island. The team spent four days conducting interviews with six people who stay out at Kendall Island during the summer whaling season. The elders were the boat drivers, navigators and teachers who took time to teach the team about fishing and whaling practices as well as told stories of lessons they learned when they were younger. The translator was the camp boss who owned the camp that the team resided. She also taught the team important lessons that related to hunting, preparing food and safety. The research participants have lived seasonally and hunted at Kendall Island for approximately 15-50 years.

In total, approximately twelve hours of interviews were transcribed, verified and themes were extracted. Interviews were transcribed and later verified by each of the interviewees. The two youth and the project coordinator transcribed all of the interviews. The project coordinator analyzed the transcribed interviews and drew out underlying themes from the interviewees' answers to various questions that ranged from cultural practices to adaptation to a changing climate. The themes were then returned to the interviewee to disapprove, approve or edit as they saw fit. The small sample size allowed for the coordinator to read and listen to all of the interviews and draw out underlying themes from each interview. The nature of the questions and small number of interviews did not allow for large, quantifiable data, but rather more of an observational set of data.

Outcomes

Analyses of the interviews revealed reoccurring themes were present and those themes are valuable for future research and monitoring designs around Kendall Island and the ISR. Here we present some of the shared observations of ecosystem change followed by reoccurring themes identified.

Elders and harvesters noted ecosystem changes from the terrestrial to the marine that require some attention for future monitoring and climate change adaptation. The permafrost thawing and slumping at camps were noted throughout the harvesting area where the historic camps remain. The Arctic islands are becoming smaller and the water is becoming shallower making it difficult to travel by boat to the coast of the Arctic Ocean. The whales are arriving earlier and earlier due to the earlier ice break up and melting in the area. Fluctuations in both beluga whales and fish were observed and were thought to be due to natural causes. If any beluga whales or fish show any signs of sickness, it is not eaten in case it will make people sick.

The following reoccurring themes were identified in the six interviews, which highlight the importance of whaling camps and harvesting activities for strengthening the culture and knowledge of the Inuvialuit:

-Only take what you need and share what you have;

-Where one chooses to hunt whales is very important and is worth protecting and preserving;

-Going out to the whaling camp every summer is instrumental in enriching one's culture and also to have a better grasp of Inuvialuktun, the native language;

-A traditional way of living brings family closer together;

-Technology is utilized more to communicate during a beluga hunt and is beneficial for assuring that a family will get a whale;

-Until someone (scientists, health professionals, family etc.) says that beluga or fish are unsafe to eat, people will continue hunting and harvesting beluga and fish for consumption;

-In terms of adaptation to a changing climate, search diligently and thoroughly for a better way of doing things and follow that way; and,

-It's not all about money, food or environment but it's important to pass down traditional knowledge for the "togetherness of the Inuvialuk".

Conclusions

This pilot study drew on the capacity and expertise of the Inuvialuit to document the observations of environmental changes and their impacts on culture and subsistence. The

Inuvialuit Settlement region is arduously working toward being able to generate research ideas and to independently conduct the research thus defining community based research (CBM). This pilot study is the epitome of CBM, which also launched a TEK local observations component of the Beluga monitoring program. To be able to document this vital work is not only documenting the participants valuable knowledge but also able to create a stronger and more dynamic foundation for further research endeavors.

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A Fish Camp Approach to Survey Research

By James Magdanz

This short statement offers some personal observations on using household surveys to collect quantitative data in small Arctic communities. First, research questions should be informed by qualitative research, including traditional knowledge, and administered with a reliable and tested survey. Given that, two methodological decisions are crucial: the number of researchers and duration of data collection. At one end of the scale are projects with long durations and a single researcher. At the other end are projects with short durations and multiple researchers .I began my agency career as a slow solo researcher and ended it as a fast team researcher, simply because a team approach worked so much better. It reduces burdens on communities and fatigue of researchers.

Over time, I came to see survey research as rather like going to fish camp. Fish are challenging to capture, and spoil quickly if not well cared for. The same can be said of data; they are challenging to collect, easy to spoil. Fish are wonderful food, when properly stored and distributed. The same is true for data; they must be properly stored and distributed. In a fish camp, there is a clear purpose. Everyone understands their roles, and knows how to use their tools. They all work hard, sometimes in great bursts of energy, and then it's over. Along the way, there can be some friendly competitions to see who can catch or cut the most fish. In conducting survey research, I consciously tried to follow the fish camp model. We had teams working towards a common goal, with controlled data collection, with careful processing, storage, and distribution, and with some friendly competition among researchers.

As momentum builds for community-based Arctic observing systems, it is easy to imagine a system built on the solo researcher model. It is hard to justify multiple social science researchers in a region, let alone in a single community. The solo researcher model also is a way to distribute employment benefits to a maximum number of communities. While there are some success stories – Bob Uhl's daily logs of environmental conditions at *Sisualik* is a wonderful example – there are many more examples of solo researchers gone AWOL. This is especially true of survey research. Asking a hundred people the same exact questions over and over again is tedious and exhausting. Unless you are a graduate student single-mindedly pursuing a degree, there are easier and more interesting ways to make a living.

A promising, uncommon approach to survey research involves indigenous researchers from multiple rural communities working together in a single community. My first limited experience with this came in the 1990s when Elizabeth Andrews asked Clarence Alexander – a Gwich'in leader familiar with survey research from the Council of Athabaskan Tribal Government's own efforts – to join survey projects in Noatak, Shishmaref, and Wales – *Iñupiat* communities. It worked extremely well, and I learned a lot working with Clarence. While project teams are often "vertically" structured, meaning urban agency or university researchers working with rural community researchers, I hope for a future with many more "horizontally" structured teams, community researchers working together, but not always "at home."

James Magdanz retired from the ADF&G Division of Subsistence in 2012. He lived and worked in Nome and Kotzebue from 1981 to 2012.He is currently a graduate student working toward a PhD in Natural Resources and Sustainability at the University of Alaska Fairbanks. Contact jmagdanz@alaska.edu

Community Paper for the 2016 Arctic Observing Summit

Theme 6: Interfacing Traditional Knowledge, Community-based Monitoring and Scientific Methods for sustained Arctic Observations

Title: **Enhancing monitoring of beluga whales (*Delphinapterus leucas*) in the western Canadian Arctic through the development of local ecological indicators**

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Introduction

The Inuvialuit of the western Canadian Arctic have harvested beluga whales (*Delphinapterus leucas*) for centuries; today, the harvest continues at summer whaling camps situated along the Beaufort Sea coast (McGhee 1988; Harwood and Smith, 2002). Beginning in the 1980s, beluga harvests were monitored in the Inuvialuit Settlement Region (ISR) in Kugmallit Bay, Shallow Bay and Kendall Island and the Paulatuk area (Harwood et al., 2015). Standardized beluga monitoring documents the size, efficiency and timing of the subsistence harvest (Harwood et al., 2015); sample collection supports the analysis of indicators for beluga diet, ecotoxicological endpoints and contaminant exposure (e.g. Desforges et al., 2013; Loseto et al., 2008a, 2008b; Noel et al., 2014; Ostertag et al., 2013).

The knowledge about beluga whales held by the Inuvialuit is associated with decades of observations, and includes hunters' and Elders' knowledge of beluga whale behaviour and predation (Byers and Roberts, 1995). Although hunters and monitors have contributed to the beluga monitoring program in the ISR through sampling and data collection, the traditional and local ecological knowledge (TEK/LEK) held by the Inuvialuit have not been explicitly recorded in the monitoring process. Therefore, this study was initiated in 2013 to record local observations and identify TEK/LEK indicators of beluga whales that could support holistic monitoring of beluga whales. This project aimed to document community perspectives and observations of beluga whales that may be used as indicators of beluga health and environmental change.

Approach

This project aimed to include all interested community members from Inuvik, Paulatuk and Tuktoyaktuk, NT, to engage in the development of methods and instruments for documenting local observations about beluga whales in the ISR. The process for developing the instruments, recording observations and interpreting results involved frequent community engagement through community meetings, interviews, semi-structured questionnaires, survey forms and focus groups in the three communities. In addition, this project aimed to provide opportunities for local employment and increased capacity for research.

Results and Discussion

This project successfully engaged community members from the predominant beluga-harvesting communities in the ISR (Table 1). Community meetings held in 2013 were well-attended and were effective for initiating the project design. In 2014, we found that the meetings were less effective for exploring findings from the data collection; therefore, we chose to use focus groups in 2015 to review the research findings and fill in knowledge gaps.

Questionnaires and surveys supported the collection of 'real-time' observations made during the harvest about beluga condition, behaviour and activity, or, opportunistic observations about migrating and feeding whales. The methods for recording shore-based observations varied between years, hence the large number of observations in 2013 and 2014 compared to 2015. Overall, community members were receptive to the use of questionnaires and surveys for documenting local observations. However, the use of questionnaires to record observations following the beluga harvest was more challenging due to the time constraints associated with butchering and food preparation.

Through interviews and focus groups, we were able to spend more time with participants, meet with more diverse knowledge-holders (e.g. women, youth, Elders, and harvesters) and reach greater depths of understanding.

The final stage of this work will be to identify potential indicators for beluga health and habitat use. The final decision on the best indicators and methods for monitoring local indicators will take place with the participation of northern research partners. We will use the following criteria to evaluate beluga characteristics that could serve as potential indicators:

1) An observation that can be recorded by harvesters, beluga monitors and/or community members;
2) an observation that is considered to be important by community members based on consensual informant responses;
3) an observation that supports or complements scientific studies; and,
4) observations that are quantifiable and/or comparable between years and/or communities.

Conclusions

The strong community engagement that was also diverse in its representation resulted in the successful collection of a broad range of observations and a depth of knowledge about beluga whales that will strengthen the beluga monitoring program. This work supports the inclusion of the Inuvialuit in strengthening the beluga monitoring program in the ISR through the development of novel indicators of beluga health and habitat use. Previous work has identified that the inclusion of all knowledge holders and users in developing research and management plans creates an enriched understanding of the changes occurring in arctic marine ecosystems and supports knowledge generation and sharing (Tengo et al., 2014).

Table 1. Participation in the LEK/TEK and local observations project by community members in the Inuvialuit Settlement Region. The annual number of meetings, research assistants and participant observations were pooled for Inuvik, Paulatuk and Tuktoyaktuk, NT, between 2013 and 2015.

Activity	**Year**		
	2013	**2014**	**2015**
Community meetings (*n*)	6 meetings >80 participants	6 meetings 51 participants	0
Focus groups (*n*)	na	na	3 meetings 28 participants
Community-based research assistants (*n*)	4	6	5
Shore-based surveys (*n*)	346	451	76
Harvester observations (*n*)	30	28	33
Interviews (*n*)	na	43	2

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Proposed Process for Use of Western Science, Citizen Based Monitoring, and Traditional Knowledge in Ecosystem Models

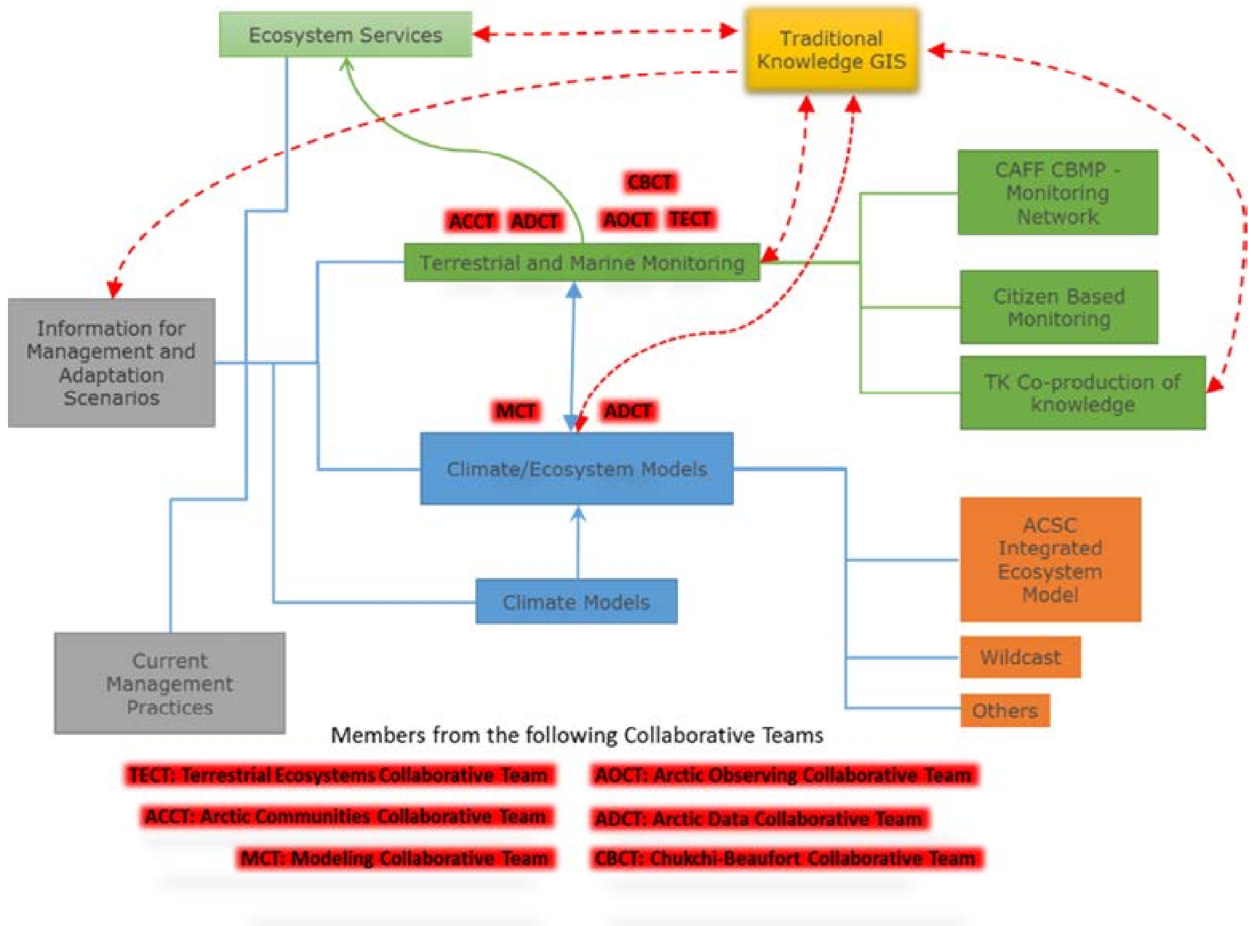
Vanessa Skean and Carl J. Markon, U.S. Geological Survey

Traditional knowledge can help detect changes in terrestrial Arctic ecosystems and guide potential adaptation responses. As the cryosphere changes, climate feedbacks may become more complex and changes in Arctic systems may occur more rapidly. Traditional knowledge, along with the systematic collection of information, can assist in identifying the effects of climate change on habitats and their use by human society. Observations of landscape conditions and trends are commonly achieved through different means of monitoring. The selection and monitoring of sites where climate feedbacks are observable is possible using existing networks and the data obtained through western science, citizen based monitoring, and the inclusion of traditional knowledge. These types of data collection build capacity for identifying, understanding, predicting, and responding to diverse environmental changes throughout the Arctic.

The inclusion of traditional knowledge into the planning for ecosystem science and adaption strategies for climate change remains a challenge. To meet the challenge, the Interagency Arctic Research Policy Committee (http://www.iarpccollaborations.org/about.html) established a milestone that would attempt to use local traditional knowledge, GIS data and integrated climate models to help understand the relationships among climate, land use change, ecosystem services, village subsistence systems, and food security. This milestone will attempt to bring monitoring data and information from a wide variety of sources together for potential input to existing climate and ecosystem models that assess spatial and temporal aspects of climate predictions and ecological change. When possible, traditional knowledge will be utilized to evaluate and enhance the modeled predictions. The climate and ecosystem models will, in turn, be available to traditional knowledge holders to assess projected changes in subsistence resources as well as an aid for fish and wildlife management.

To implement this milestone, six of the 12 IARPC Collaboration Teams will potentially be involved: Terrestrial Ecosystems, Arctic Data, Modeling, Arctic Observing, Arctic Communities, and Chukchi-Beaufort Seas. Figure 1 shows a generalized depiction of the process. Solid lines indicate direct and open transfer of information to/from organizations. Dashed lines indicate selected information transferred from/to traditional knowledge holders depending on the need and proprietary nature of the traditional knowledge in question; the Traditional Knowledge (TK) GIS component is totally separate from the rest of the processes as far as connectivity because some of the TK information is considered sensitive and proprietary tothe local knowledge holders. This process however, would give TK GIS owners the ability to accept a wide range of information to analyze in their GIS systems, but also allowing them to release what they consider appropriate for public or limited government use. Thus, the resulting GIS data and spatial applications represents a potentially valuable source of information for subsistence users, resource managers, and scientists studying climate and ecosystem processes.

Figure 1. IARPC Implementation of Milestone 3.2.3.a - Using collaboration teams to help transfer different types of knowledge for climate associated management and adaptation decision making.



Briefing Note On Traditional Knowledge Sources From The Internet

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This briefing note addresses the use of traditional knowledge (TK) data sources from the internet, the associated ethical issues and challenges, and provides an example of a situation that poses such challenges – community based monitoring platforms.

The global rise in social media platforms and users has resulted in a concomitant increase of Indigenous Peoples, communities and organizations sharing information based on their knowledge and experiences publicly on the internet. Social media platforms are significant venues for Indigenous Peoples to communicate within and between communities about environmental knowledge, gathering food, social and cultural activities, and changes that are occurring, among other topics. Some western science researchers have expressed an interest in gathering (and have begun to gather) such information, framed as "Traditional Knowledge", for use in research. Information from TK should not be solely gathered through the use of social media (including Facebook posts, public environmental observation program websites or other platforms). Widespread access to this type of information raises several concerns and challenges, particularly related to ethics and scientific and TK rigor.

Though individuals are sharing information on public platforms, there are troubling ethical questions around research practices that gather data from these platforms. Many people unknowingly share information on websites/portals without understanding or reading the use agreements that may give others ownership of the information shared. With information available on the internet, it is difficult to control use rights, access to information, or how it is used. The absence of informed consent is inherent in the use of publicly available information today (e.g., Facebook and many applications on smart phones). It is important to ensure proper documentation, management of information, as well as involvement of TK holders to ensure that TK is not taken out of context or misinterpreted. Research protocols and policies need to be established for web-based information gathering to ensure that individuals and communities are not harmed by the information collected or its use, that research rigor is maintained, and that information is used ethically.

Information from TK must be collected and documented with rigorous social science and/or TK methodologies. TK is not evenly distributed throughout indigenous communities. While researchers may want to harvest digital information from online sources, without proper engagement of communities, particular knowledge holders, or a formal research agreement, it may be impossible to determine who a TK holder is, and who may be a community member, but not an individual considered *by* their community to be a TK holder or expert. It is also difficult or impossible to determine if information shared on a public website has been vetted through the proper channels. The collection of information must always be in direct collaboration with TK holders. This includes (but is not limited to) free, prior and informed consent, development of research questions and protocols, analysis of information and review and approval of research products. Many TK holders participate in social media and share information from their knowledge via online platforms; however, using social media as a sole data source for TK documentation is unacceptably problematic (e.g., the data is not contextualized, sampling errors).

As one brief example, community based monitoring (CBM) projects have received much attention in the last decade. As stewards and residents of the Arctic, Indigenous peoples are the first witnesses to changes that are occurring and hold detailed and complex knowledge of the relationships between Arctic systems. As such, researchers and government agencies recognize the many benefits of including Northern Indigenous communities in their research, often viewing Indigenous communities lining the coast of Arctic countries as an inexpensive source of environmental monitoring and information gathering. The challenge that we face is in ensuring that the needs of the communities are equally addressed and that the utilization of information from TK is done in an ethical and sound manner. Equally important is the identification of who is providing the information into CBM projects; as a result, data-bases must be clear and transparent.

Another important consideration is the identification of knowledge holders, because of the different levels and distribution of knowledge within communities. For example, a 20-year old with no hunting experience, or someone who has no experience with fish but is talking about fish, is an example of an individual that may not be considered a TK holder or be following TK practices. CBM programs that solicit observations/information from any and all people are not the same as a program based on TK. These considerations for TK-based CMB projects are also true for the use of other social media or internet-based information.

As we move forward with the use of the many technological tools available today ethical, scientific, and TK rigor cannot be forgotten. It is important that we apply the same standards to information gathered on or off of the Internet.

Witnessing 100 years of the sub-Arctic region's climatic variability: sheep farming in southern Greenland

Naotaka Hayashi, University of Calgary

Sheep farmers in southern Greenland are witnesses to a recent and historical changing climatic conditions. Since sheep farming is directly influenced by weather conditions, seasonally and yearly, the developmental history of sheep farming reflects a hundred years of local adaptation to the changeable climate of the sub-Arctic region. In southern Greenland, approximately 22,000 lambs and sheep are processed yearly and distributed within Greenland. In addition to seal meat and dried cod, lamb is regarded as traditional food in Greenland.

History

1) The reintroduction of animal husbandry

At the turn of the 20th century, the paternalistic colonial policy of Denmark reintroduced sheep farming to Greenland. Because of low prices of blubber oil and the persistence of subsistence fishing, Greenland industry was underdeveloped from a Danish point of view. The Danish authority intended to give a "sideline" to Greenlanders (Inuit descendant inhabitants in Greenland). The reintroduction meant the revival of animal husbandry after the demise of Norsemen communities in the 15th century, just before so-called the Little Ice Age. Greenland has been under the sway of a big historical climate cycle. The Danish attempt of reintroduction of sheep raising was successful partly because of a rising trend in temperature at that time, which became apparent during the 1930s. Local sheep farmers tell that their previous generations experienced this warming trend.

2) The early stage of sheep raising in southern Greenland

In 1917, the Danish authority established a sheep breeding station at the town of Qaqortoq, southern Greenland, in order to promote sheep raising among Greenlanders. Gradually seal-hunting Greenlanders picked up an interest in this new kind of livelihood (i.e., sheep raising). The total number of sheep kept (ewes) in southern Greenland surpassed 5,000 by 1930, continuously increasing to approximately 10,000 in 1936, and reached 22,000 in 1948. By the 1950s, one in five kept sheep in southern Greenland. Sheep raising clearly took hold in the society as an important economic activity.

3) The establishment of today's sheep farming

In 1924, one Greenlander started to make a living at Qassiarsuk exclusively by sheep farming. This is the origin of today's large-scale, professional sheep farming. Before long, full-time sheep farmers' community was also established at Igaliku. After the 1930s, full-time sheep farmers began to appear along the inner part of the fjords towards the south, near the town of Nanortalik. They were unique because, at that time, most people were small-scale, part-time sheep farmers. Statistics show that in 1948 among 264 sheep farming, as many as 212 of them (about 80%) kept only fewer than 100 sheep.

The form of sheep raising started to change after several harsh winters. Recurrent cold spells squeezed many sheep owners' households. At that time, sheep owners would let their animals loose in hills and mountains all year around, even during the winter months. In the inner fjords of southern Greenland, a cold wind and a warm foehn wind (a Chinook-like wind) alternate, which results in a wide fluctuation in temperature. Once covered by ice, pastures are not accessible to animals. In a harsh winter, many sheep starved to death. The number of sheep declined from 22,000 to 9,000 in 1948-49, from 23,000 to 17,000 in 1956-57, and from 47,000 to 22,000 in 1966-67. Particularly, after the 1966-67 winter, many sheep owners stopped keeping sheep. By regulation, sheep has been slaughtered and processed at a slaughter house. A decline in meat production reflects historical harsh winters (Figure 1).

By the 1970s, it became clear that a small-scale sheep raising was not profitable and that sheep raising should be upgraded. The sheep breeding station was moved from Qaqortoq to Upernaviarsuk, northeast of the town in the same fjord, being upgraded to the agricultural research station. Further, in the 1970s, its administration was transferred from the Danish to Greenlanders. When Greenland gained autonomy from Denmark in 1979, the Greenland government enforced regulations which required sheep owners to stable their animals during winter and to provide sufficient fodder for their animals. Accordingly, small-scale sheep owners declined in number while large-scale, full-time sheep farmers survived because they were able to afford to build and renew sheep sheds and to grow grasses during summer. Today, no one keeps sheep as a sideline. Although Greenlanders lost a form of sheep raising as a sideline, about 50 full-time, large-scale (300 to 700 sheep per farm) sheep farms have been established. Sheep farming has now became a new tradition in southern Greenland, establishing a strong presence in Greenlandic culture.

The vertical linkage of support system in sheep farming

A review of the history of sheep farming in Greenland shows coordinated efforts to cope with climatic variability and anomalies. Sheep farmers created associations in different communities to help each other. The agricultural research station (at Upernaviarsuk) has a farming school to train youngsters to become the next generation's responsible farmers, and the state agricultural advisory office assumes the role of pipeline between government and farmers. In light of climate change, farmers' adaptive capacity has been built through this vertical linkage from the local to national level. In a sense, sheep farming developed by coping with abruptly changing weather conditions in winter.

Now that farmers confine their animals during the winter season, farmers' current concern is weather in the summer instead. Recently, Greenlandic sheep farmers are observing drier summers that substantially affect the production of grasses – fodder making for winter stabling. The government offers subsidies on well favourable terms when farmers expand their fields, so that they can cultivate arable areas in order to increase their hay production. In the event of a bad harvest, farmers buy fodder from foreign countries, such as Norway, to supplement the shortage, through the federation of sheep farmers' associations. Although it may create a dependency of farmers on government, this vertical linkage is still helpful for sheep farmers to cope with abnormal summer weather conditions.

Information exchange across scales

In the years 2008, 2009, and 2015 when I did my fieldwork, dry summer conditions were the primary concern of sheep farmers. Although farmers can supplement the shortage of grasses by importing fodder from foreign countries, unfavourable weather conditions caused financial burden on farmers. Some farmers used sprinklers for their fields drawing water from the nearest river. A few farmers built a small hydroelectric generator at river in order to cut the expenditure for fuel. These mitigation measures were also assisted by government subsidies through the agricultural advisory office.

Sheep farms spread along the coastlines of the inner fjords. Local weather conditions vary from place to place. Farmers communicate local information at occasions such as sheep farmers' association's meetings and causal visits to town. In addition to the horizontal information exchange, farmers' information is moved to upper scales such as the federation of sheep farmers' associations and government. The media (the Greenland national broadcasting corporation) also takes a role in information transmission to communities in the form of radio and TV news. Farmers expect that the government can take swift action to mitigate damage caused by unusual weather conditions, based on smooth communication at all scales.

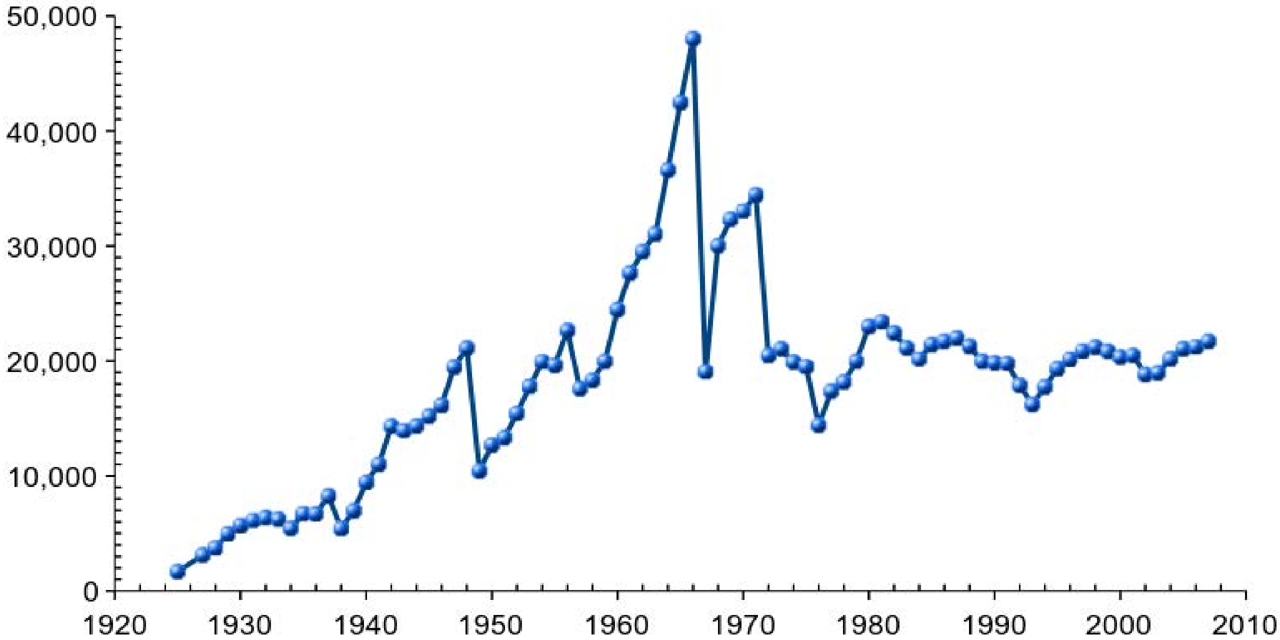

Figure 1. The number of sheep slaughtered and processed between 1925 and 2009