

## **Adaptation in a Changing Arctic: Ecosystem Services, Communities and Policy**

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## Abstract

This project documents the changing physical, biological and socio-economic conditions that are affecting people in the Arctic and identifies policies and strategies to assist communities in dealing with these changes. The project builds on previous work on the vulnerabilities of Arctic communities, and it is feasible because of established collaborations with northern people and organizations. The project includes case studies in all four of the ArcticNet IRIS regions. One main focus of the project involves integrating scientific and traditional knowledge of ice, permafrost, coastal dynamics and wildlife with information about community use of these ecosystem services. The other main thrust is to identify the opportunities in existing policies and co-management arrangements for adaptation strategies to help communities deal with changing conditions.

## Key Messages

This project provides insights into how Arctic communities experience changing climatic conditions and outlines how people and institutions adapt to such changes in the context of other forces of change. Findings from this project have been published in numerous scientific journals, books and reports, and have been disseminated through stakeholder meetings, media and presentations at conferences and workshops. An overview of many of the findings is published in Pearce and Smit (2013) "Vulnerability and Adaptation to Climate Change in the Canadian Arctic". As Mary Simon (among others) has stressed, there is an urgent need for insights into the processes and opportunities for communities to adapt to changes in the Arctic environment. Key messages from this project include:

- Communities across the Arctic are continuing to experience many changes, including in climatic, ecological and socio-economic conditions. For many communities climate-related conditions, such as changes in ice dynamics, already have

important implications for livelihoods and health. For some communities (e.g. Baker Lake, NU) mineral exploration and mine development is a profound force of change.

- Climate change is not experienced separately from other forces, and adaptations are adopted (and need to be undertaken) in the context of multiple stresses. One example is in the context of travel safety in Nunatsiavut where individuals' safety on land is influenced and contextualized by weather, long term sea ice changes, access to equipment, financial resources, knowledge and planning strategies to adapt to changing conditions undertaken before and during sea ice travel.
- Adaptation and enhancing adaptive capacity occur at multiple levels, and involve adjustments to ecosystem changes by individuals, communities and policy making institutions, including co-management bodies.
- Traditional knowledge provides valuable insight into ecosystem changes and contributes to enhancing capacity when integrated within management policies and decision making processes. This is illustrated in detail in studies in Ulukhaktok and Tuktoyaktuk.
- The progression from dissemination of findings to knowledge exchange and co-production is important for effective enhancement of adaptive capacity. Adaptations involve mutual learning or the co-production of knowledge, and this is occurring through collaboration amongst northern residents and scientists, policy makers and managers.
- At the community scale, there is little evidence that mining is augmenting adaptive capacity; indeed the institutional arrangements that govern mine development have added to historical processes of disempowerment. At the individual scale, however, there is considerable evidence that has augmented capacity is largely a result of increased household incomes.
- A better understanding of how northern communities link their material, relational and

subjective wellbeing to ecosystem services (e.g., water) is pointing to new metrics and indicators to assess climate change adaptation.

- Examination of sense of place and place identity provides improved understanding of the subjective or values-based dimensions in northern communities that are crucial for effective climate change adaptation. Drawing upon art and artistic processes is a novel way of fostering collaboration and dialogue among a diverse range of actors to understand environmental change and culturally meaningful ways of addressing change.
- Supporting efforts that increase financial, health, educational, and cultural capacity in a community will often also enhance the adaptive capacity of the community to deal with current and projected future climate change risks.
- Further analysis and investigation of adaptive capacity and the significant role of institutional arrangements and policy interventions is necessary to reduce vulnerability across the Canadian North. For example, the changing role of institutionalized Search And Resource (SAR) support in supporting safe travel on the land is potentially important in the context of adaptation to sea ice changes in this region in the future.

## Objectives

1. To integrate natural and social science and Indigenous Knowledge in vulnerability assessments.
2. To examine the institutional structures and processes which facilitate or constrain adaptation to changing conditions in Arctic communities.
3. To engage northern communities in assessments of adaptation strategies and options.

## Introduction

The assessment of vulnerabilities and adaptations in and for northern communities has been identified as a priority

area for research by policy-makers, local and Indigenous communities, the Arctic Climate Impact Assessment (ACIA), and the Arctic Human Development Report (AHDR) (ACIA, 2005; AHDR, 2004; Denmark Ministry of the Environment, 2004; Government of Nunavut, 2003; ICARP, 2005; McCarthy and Martello, 2005; NRI, 2002; Watt-Cloutier et al., 2005). More specifically, there is a need for research that assesses vulnerabilities, provides insight into adaptation strategies and enhances adaptive capacities based on incorporating multiple sources of knowledge and including multiple scales of analysis from local to global.

This project directly addresses ArcticNet's central objective, "to generate knowledge and assessments needed to formulate adaptation strategies and policies that will help northern societies and industries to prepare for the full impacts of the transformation of the Arctic". The research aims to document and describe the physical, biological and socio-economic conditions that Arctic societies need to adapt to today and will likely be faced with in the future, and it identifies opportunities and institutional processes for effective strategies and policies to deal with changing conditions.

The project builds on the accomplishments of ArcticNet 4.2, which documented vulnerabilities in a set of northern communities where researchers have completed baseline vulnerability assessments and have established relationships with stakeholders. This experience affords an opportunity to develop longer-term research collaborations than is normally possible within the constraints of most research programs, to address gaps in existing research such as the need to further integrate natural and social science research on relevant exposure-sensitivities faced by these communities, and to systematically analyze the ways in which community-level adaptations are facilitated or constrained by institutions and policies at higher levels.

## Activities

Overall, activities in 2012-2013 were directed towards improving our understanding of the nature of Arctic

community vulnerability to changing conditions (across a range of locations and situations), and towards widely disseminating findings (in major scholarly journals, books and other outlets), and towards continuing to build on-going collaborative arrangements to facilitate participation and community-engaged research. Activities across sub-projects contributed to the three project objectives simultaneously, and were undertaken in several main areas.

- Research initiatives in several sub-projects examined the interaction of multiple forces of change in Arctic communities. This theme was explored (and/or reported on) with respect to Ulukhaktuk (NWT), Tuktoyuktuk (NWT), Baker Lake (NU), Nain (NFL), Hopedale (NFL) and Fort Resolution (NWT).
- The process of “knowledge exchange” represented a common integrating focus among sub-projects. For example, knowledge translation was a central activity in Nain (Furgal and colleagues). The intergenerational transfer of traditional knowledge about the environment was a key focus in Ulukhaktuk (Pearce and colleagues). Knowledge mobilization activities were important parts of the work in Baker Lake (Bradshaw and colleagues). The issues of bridging scientific and traditional knowledge, co-generating knowledge and the use of artistic processes for effective communication in northern communities were developed (Armitage and colleagues).
- Numerous activities were directed to establish and maintain the collaborations necessary to complete the research in this project. These collaborations were with:
  - » communities and community representatives;
  - » government agencies and co-management organizations;
  - » industry and business representatives;
  - » other scholars and research groups, both within ArcticNet and beyond;
  - » international organizations and colleagues.
- Significant activity was devoted to continuing to ensure that the research and its findings are disseminated widely. In particular, the research was published in numerous refereed scientific journals. The findings were also published in books and reports, presented at a wide range of conferences and workshops, and shared via community meetings, radio and TV interviews and other media reports.
- The project team (Pearce, Smit, Furgal and Bradshaw) contributed to the ArcticNet IRIS I Regional Impact Assessment (Stern, ed.), with Ford, Duerden and Dawson.

The importance of knowledge bridging (traditional, scientific) with regard to community adaptation to Arctic change, and for more effective decision making, was examined. A new ArcticNet doctoral student has been recruited for one aspect of this theme (Rathwell). Contributions are being made in advancing a typology of approaches to bridge knowledge systems through art and governance. The concepts were presented at several venues (including ArcticNet) and a paper is in preparation for submission to *Global Environmental Change*. A book chapter linking several of these themes is in press (Armitage 2013). Additional emphasis on using art and artistic processes as a basis to engage northern communities in assessments is underway and has incorporated the participation of Dr. I Mauro (Canada Research Chair, Mt. Allison University).

An on-going initiative has been examining social wellbeing and place identity as a lens to understand vulnerability and respond to change. Support for a new ArcticNet MES student (Carter) is enabling further work on this theme. Carter recently participated in the Cumulative Impact Monitoring Program (CIMP) workshops in Yellowknife. Part of this research is published in *WIREs Climate Change* and in a forthcoming paper in the *Indigenous Policy Journal*. Further papers are planned for the coming year.

Focusing on the themes of institutional structures and processes which facilitate or constrain adaptation:

- Armitage led a two-day symposium on transboundary water governance, inviting several

individuals from NWT, and other experts in the Mackenzie Basin context. The Mackenzie Basin was used as the core example around which discussions revolved

- Armitage was invited to give a talk to the Ecohydrology Group, University of Waterloo, June 5th, 2012 on linking science and policy to address the problem of fit in aquatic systems and drawing on the NWT/Mackenzie Basin context
- Fresque-Baxter and Armitage presented a talk on assessing the link between place-based relationships and changing water resources in a session on Vulnerability, Resilience and Adaptation at the International Polar Year Conference, Montreal, Quebec. April 23, 2012.
- Armitage was invited to provide a peer-review critique of WWFs emerging Arctic ecosystem services and stewardship strategy

Focusing on efforts to engage northern communities in assessments of adaptation strategies and options:

- Carter participated in the NWT Environmental Monitoring Annual Results Workshop that was hosted by the NWT Cumulative Impact Monitoring Program (CIMP), Government of the NWT and the Department of Fisheries and Oceans (DFO), January 20-27, 2013. She wrote a blog post on the experience and outcomes.
- Rathwell participated in the EnRich workshop on community resilience and spoke on the opportunity to bridge knowledge systems through art and governance to navigate environmental change, November 27-30, 2012 in Ottawa.
- Rathwell developed a poster for a competition to develop the “best solution to address complex environmental change”, by developing an idea for ‘Art + Science Alchemy’. She wrote a blogpost on this competition.

The on-going participatory research on climate change vulnerability and knowledge transmission in Ulukhaktok, NWT was undertaken by Tristan Pearce

in collaboration with Smit and others. This work addressed the three project objectives, and included the dissemination of findings regarding environmental change and Inuit communities in the Arctic.

Publications and other research products included the overview paper (Pearce & Smit, 2013), and other products, many of which reflected collaborations with community residents, other ArcticNet scholars and researchers from elsewhere.

Pearce spent six weeks in July/August 2012 and six weeks in January/February 2013 in Ulukhaktok. His research activities included:

- Disseminating findings regarding environmental change and Inuit communities at the school, on the radio, and at community organization meetings.
- Collecting data on the economic status and role of hunters in the community in the context of changing climatic conditions;
- Collecting data on Inuit food preferences as a precursor to a forthcoming research project that will examine food security in a changing climate;
- Developing a new research project on knowledge transmission among Inuit women;
- Collaborating with Dr. Peter Collings of the University of Florida to examine food sharing networks and their role in adaptation to the health effects of climate change.

Two manuscripts have been prepared and submitted for publication based on these activities: (1) Inuit Food Preferences; (2) Inuit Knowledge in Adaptation to Climate Change in the Arctic.

Smit and Pearce are continuing to work with international research partners on comparative studies of community adaptation to climate change across the Circumpolar North. This involved information sharing across case studies and the development of an international collaborative research paper, on which Pearce and Smit are the lead authors. Pearce will meet with international partners in Tromsø, Norway in May 2013 to complete manuscript preparation

and submission to a peer-reviewed journal. Smit and Pearce are also working on a comparative analysis of knowledge exchange processes relating to climate change adaptation in Indigenous communities with colleagues in National Institute of Water and Atmospheric Research (NIWA, New Zealand).

Included in collaborative activities resulting in publications was the paper by Andrachuk and Smit on community vulnerability in Tuktoyaktuk, NWT. Results from the collaboration with Fleming and others on adapting to climate change in Hopedale, Nunatsiavut were also published. Collaboration with Simon Fraser University on climate change, marine ecosystems and ocean resource management options is continuing, building on a presentation at the European Climate Change conference, and with a journal paper near completion. Insights from our Arctic research were also included in the publication by McLeman, addressing climate change and Canadian security and in the NRCAN Climate Change Adaptation National Assessment. The relationship between sea ice change and cruise ship tourism in Canada's Arctic have been explored by Dawson and colleagues.

With support from Ben Bradshaw and Hamlet ASAO, Robert Seeteenak, Research Associate, Zoe Barrett-Wood, spent April and May 2012 in the Hamlet of Baker Lake using community radio (2 noon-hour call-in shows) and evening workshops (3 in total) to: 1) communicate results from summer 2011 research, which aimed to document the Hamlet's experience with mining (completed by Kelsey Peterson); and 2) mobilize knowledge of Aboriginal community experiences with mining from elsewhere.

These efforts were complemented by Ben Bradshaw's ongoing communication with the Hamlet Mayor and Council, including a formal presentation at a Council meeting. Though appreciated by some, the Hamlet expressed frustration over their inability to more systematically measure change in community conditions given mining and other forces of change. This led to the development of a new long-term monitoring project that began with Masters student, Sophie Maksimowski, completing a 3-month field season (July – September 2012) in the Hamlet

identifying indicators of community health and capacity in the context of mine development.

With assistance from community researcher, Britania Twyee, and Hamlet ASAO, Robert Seeteenak, Sophie completed 45 individual interviews and organized 6 focus groups with women and youth. This work is being supported with complementary funding from Agnico-Eagle Mines Ltd. and Mitacs. Finally, in September, Ben Bradshaw and Colleen Davidson visited the Hamlet to mobilize knowledge from the 2011 field studies and a complementary CIHR-funded knowledge synthesis project focused on mining and Aboriginal community health.

Furgal and Durkalec completed data analysis and conducted data validation and project results return and knowledge translation activities in Nain and Happy-Valley Goose Bay in June 2012. At this time meetings with project collaborators/partners were held to check interpretations of project data and to hold community information sessions to report preliminary results back to participants, the community and key organizations (Nunatsiavut Department of Lands and Resources, Environment Division; Department of Health and Social Development; Nain Ground Search and Rescue). Reporting of results was done in combination with other ArcticNet projects on health and environment interactions and policy implications in Nunatsiavut led by Furgal (see project reports by Hik and Furgal, Furgal and Chan, and Furgal and Sheldon). Further, a regional radio interview and discussion was conducted with Okalakatiget TV and Radio to disseminate findings to all coastal communities. A Durkalec finalized all revisions and writing of her MA thesis and successfully defended in December 2012; manuscripts have been in preparation and submission phases since that time.

Further, in collaboration with the project led by Bell and Forbes and that led by Bell and Sheldon, Furgal, and MA students Knight and Kouril participated to workshops in Nunatsiavut communities as part of the SakKijânginnatuk Nunalik (Sustainable Communities) initiative established by the Environment Division of the Nunatsiavut Government (NG) in partnership with the Joint Management Committee of Nunatsiavut. The

goal of this initiative is to develop adaptive solutions to address community sustainability challenges. Workshops were held in all coastal communities to discuss key sustainability constraints and opportunities related to development and community futures.

## Results

Detailed results have been reported in more than a dozen journal articles and book chapters, in addition to numerous reports and conference presentations (at ArcticNet, IPY meetings and beyond). We present here some representative examples of the many results obtained and/or published in 2012-13.

### *Transmission of Environmental Knowledge*

The transmission of environmental knowledge and land skills was studied among Inuit men in Ulukhaktok, Northwest Territories, Canada. A list of 83 skills important for safe and successful harvesting was generated with 14 active hunters and elders, and examined with a sample of 47 men. The research found that there is a difference in the rate of land skills transmission among generations, with average transmission rates lowest among younger respondents

Table 1. Transmission of Land Skills, Mean Scores by Groups of Skills, by Percentage.

Groups of Land Skills	Percentage Reporting the Skills					
	18-34 years (n=28)			35-49 years (n=11)		
	HO	O	N	HO	O	N
General hunting and traveling skills (x=5)	95	4	1	100	0	0
Re-load bullets (x=1)	18	43	39	64	27	9
Dog team skills (x=2)	39	19	42	73	27	0
Camp-related skills (x=8)	87	8	5	100	0	0
Light and tend a kulliq* (x=1)	11	64	25	27	18	55
Fishing skills (x=3)	94	1	5	100	0	0
Caribou hunting skills (x=4)	84	6	10	100	0	0
Musk-ox hunting skills (x=4)	74	14	12	100	0	0
Seal hunting skills (x=7)	43	29	28	79	9	12
Duck hunting skills (x=3)	100	0	0	100	0	0
Polar bear hunting skills (x=3)	23	12	65	91	6	3
Wolf hunting skills (x=3)	26	14	60	85	0	15
Trapping skills (x=3)	50	11	39	88	0	12
Fur preparation skills (x=6)	25	46	29	79	16	5
Navigation and wayfinding skills (x=7)	45	14	41	94	0	6
Travel on the sea-ice (x=3)	54	8	38	97	3	0
Weather forecasting (x=5)	39	25	36	64	7	29
Equipment making and repair (x=15)	51	17	31	82	10	8
Average (x = 83)	56%	17%	27%	87%	6%	7%

HO: learned by hands-on experience, O: learned by observation only, N: not learned, x: number of skill items, n: number of respondents, \* Inuit stone lamp

(Table 1). Several skills had not been transmitted, or were transmitted incompletely among younger respondents, whereas these same skills had been transmitted by that age among older Inuit. Changes in skills transmission are attributable to changes in the educational environment, loss of native language, absence of skills teachers, and declining levels of involvement in some subsistence activities. These factors appeared to impair the traditional mode of skills transmission and hands-on learning in the environment, resulting in several skills not being transmitted to younger respondents. Incomplete skills transmission has already reduced some individuals' involvement in subsistence, and has increased the sensitivity of others to changing climatic conditions. The findings from this research were published in the journal Human Ecology.

### *Inuit Traditional Knowledge (IK) and Adaptation*

Tangible aspects of hunting knowledge and land skills underpin key adaptations in the subsistence hunting, fishing and trapping sectors. Despite the documented importance of IK in adaptation and in maintaining a level of competency in subsistence, the relationships between IK and adaptation to climate change are not well defined, and efforts to support the transmission of IK are largely absent from climate change adaptation policy. The relationships between IK and adaptation to climate change were documented drawing on case study research with Inuit across the Canadian Arctic. IK is considered an element of adaptive capacity, which is expressed as adaptation if drawn upon to adapt to changing conditions. This depends on the development, accumulation, and transmission of knowledge within, and among generations. Efforts to support active participation in subsistence and knowledge transmission should be included in climate change adaptation programs in northern Canada.

Adaptive capacity is influenced by many, often inter-related factors operating at different scales. For example, the ability to adapt to changing travel routes on the land or ice may require using alternative

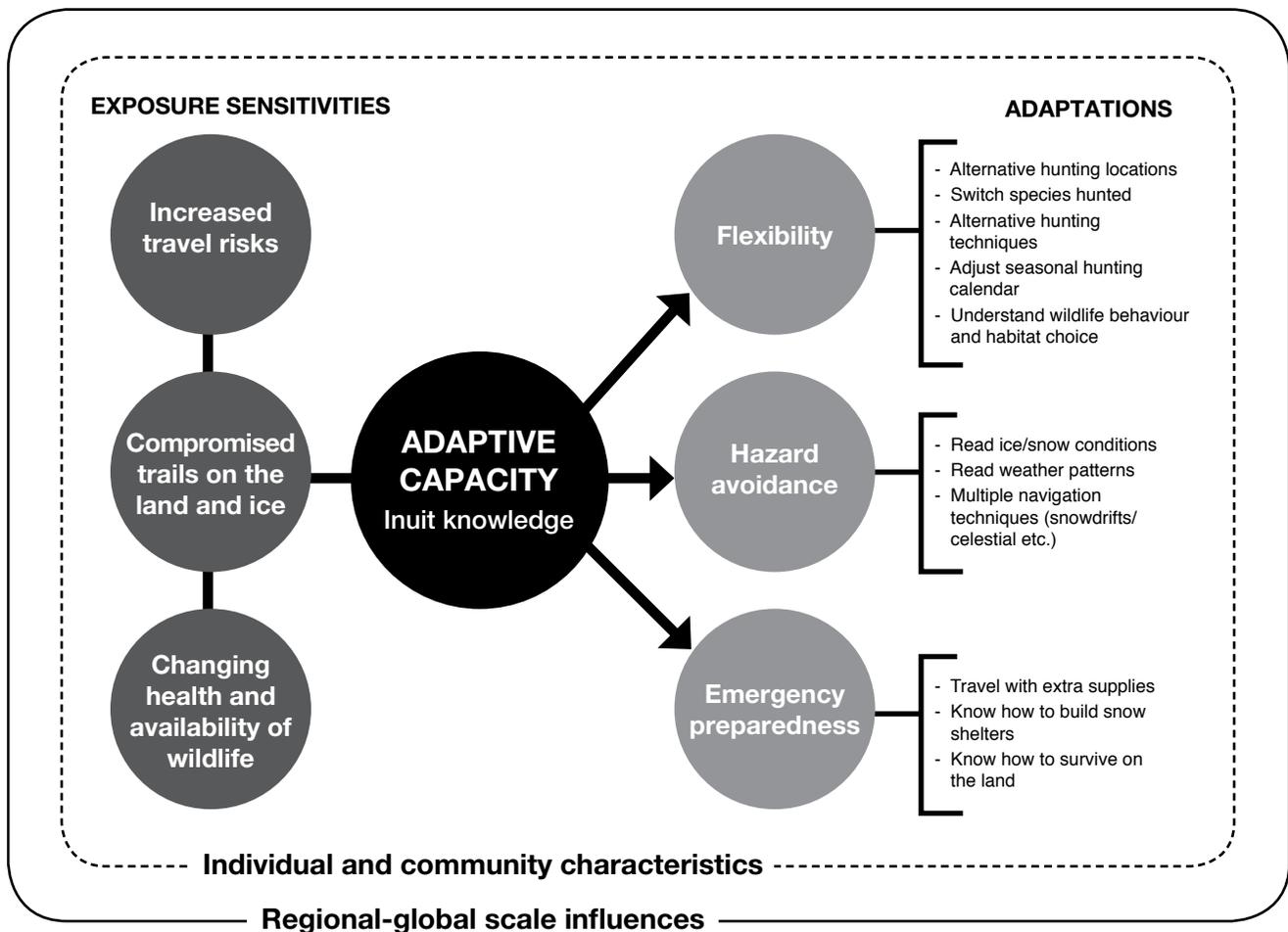


Figure 1. Adaptive capacity and exposure sensitivities.

modes of transportation (e.g. a boat instead of a snow machine) and hunting in unfamiliar locations. In this instance, adaptation hinges on the capital resources held by the individual (to acquire the hunting equipment and supplies) and/or social capital (e.g. equipment sharing) together with the knowledge necessary to travel and harvest in unfamiliar locations, and the availability of time to participate in the harvest. In terms of scale, ‘health and well-being’ may contribute to individual or household capacity whereas ‘flexibility of resource management regimes’ enhances the capacity of several stakeholders in a community.

A common perspective on the relationships among adaptive capacity, its determinants, and the process

of adaptation itself focuses on ‘the realization of adaptive capacity’ (Brooks, 2003) or ‘manifestation of adaptive capacity’ as adaptation (Smit and Wandel, 2006). In this context, adaptive capacity is described as a set of resources that represent an asset base from which adaptations can be made (Smit et al., 2000; Brooks, 2003; Vincent, 2007). Figure 1 illustrates how adaptive capacity can be translated into adaptations to respond to documented climate-driven exposure-sensitivities among Inuit in Canada. The figure simplifies the adaptation process by highlighting one determinant, IK; however, multiple determinants of adaptive capacity will most often work together in the adaptation process.

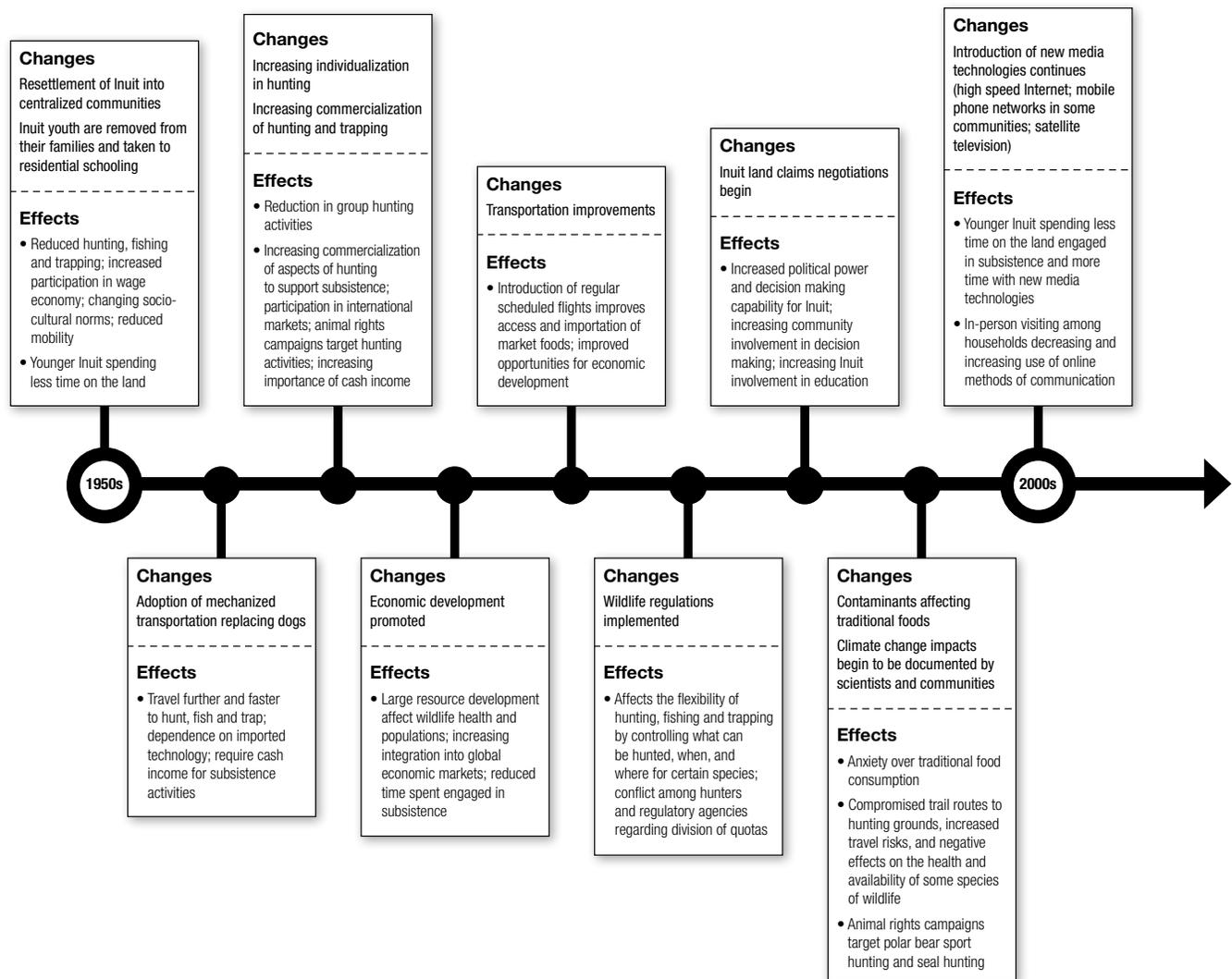


Figure 2. Adaptive response to climate change.

Several adaptive responses to changing climatic conditions affecting subsistence hunting, fishing and/or trapping have been documented among Inuit in the Canadian Arctic (Figure 2). These include flexibility with regard to seasonal cycles of harvest and resource-use, hazard avoidance due to detailed knowledge of the local environment and understanding of ecosystem processes, and emergency preparedness including knowing what supplies to take when traveling and how to respond in emergency situations. Each of these responses is closely associated with IK, the generation, accumulation and transmission of which is influenced

by a synergy of factors operating at individual, community, regional, and global scales.

### **Place, Identity, and Climate Change Adaptation**

Research results on this theme relate to the project objectives by addressing: a) adaptation through better understanding of place and wellbeing by engaging northern communities in assessments of adaptation strategies, with a focus on water resources; and b) knowledge co-production for learning and adaptation to changing conditions through institutions and governance. Key findings include:

- Impacts from climate change are affecting local places. Loss of traditional territory, lifestyle, and place-based connections results in loss of community resilience and capacity (coupled with other drivers of change), and more generally, implications for wellbeing. Place identity has a crucial role in developing appropriate adaptations/interventions and requires close cooperation with communities to reflect on options.
- We developed a working typology of three interconnected place identity approaches to help elucidate this relationship and provide context for analysis of adaptation options: 1) ‘cognitive-behavioral approach’ reflecting how place identity shapes climate change perceptions and behavior; 2) a ‘health and well-being approach’ to link the health and well-being of impacts from climate change on place and identity; and 3) a ‘collective action approach’ showing how place identity is a mechanism to foster collective opportunities for climate change adaptation. Each approach has strengths and weaknesses, depending on the contexts within which they are used. Further testing of the approaches is required, but parts of the typology are being used (or are being considered for use) to frame other research projects in the team.
- The typology is a starting point for assessing the relationship between place identity theory and climate change adaptation. By bridging these perspectives, locally appropriate strategies for climate change adaptation can be developed that account for objective realities (financial, human resource constraints) as well as the unique and intimate relationships people have with place.
- Research results on the relationship between water, wellbeing and place illustrate the connection. The importance of biophysical and human aspects of water vulnerability is well understood with efforts to understand water vulnerability in the context of climate change a crucial issue in the North given emerging

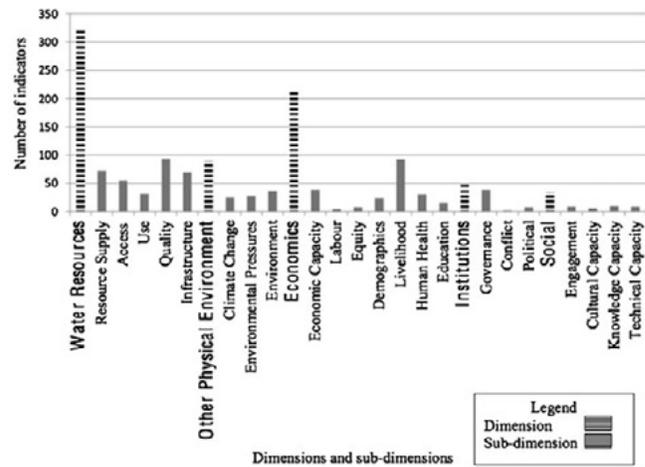


Figure 3. Summary of results of a survey of water vulnerability assessment tools including the Arctic Water Resource Vulnerability Index (AWRVI) to determine knowledge gaps (from Plummer et al. 2012).

drivers of climate change and other development pressures. An allied project (A meta-analysis of water vulnerability assessment tools) shows concerted efforts are required to enhance social and institutional considerations in assessments, specifically with regard to adaptation, institutions and governance (Figure 3). There is a need to improve existing assessments by incorporating social and institutional variables but capturing and measuring these aspects in meaningful ways is challenging.

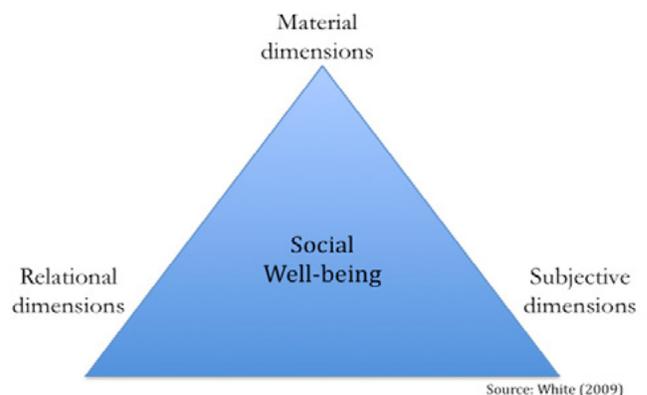


Figure 4. Wellbeing framework for understanding linkages to place, wellbeing and social attributes crucial to adaptation assessment (from Armitage et al. 2012).

Table 2. Example variables and indicators of social wellbeing (from Armitage et al. 2012).

Dimension Material	Example variables <ul style="list-style-type: none"> <li>• Income, wealth, assets</li> <li>• Physical health</li> <li>• Ecosystem services (natural capital access)</li> <li>• Institutions</li> <li>• Markets</li> </ul>	
Relational	<ul style="list-style-type: none"> <li>• Social ties (e.g., strength, diversity)</li> <li>• Trust</li> <li>• Social learning</li> <li>• Equity</li> <li>• Leadership</li> </ul>	Human agency
Subjective	<ul style="list-style-type: none"> <li>• Identity</li> <li>• Perceptions, aspirations</li> <li>• Beliefs, values, norms</li> <li>• Satisfaction</li> </ul>	

- We are using the insights from this meta-analysis to show how integrating human perceptions in conjunction with the bio-physical parameters of vulnerability is yielding a more comprehensive understanding of environmental change (e.g., to water resources). This has implications for how we propose and consider various adaptation options. Understanding of the interplay between water resources and social well-being (e.g., material, relational, subjective) is a recognized gap in the NWT Water Stewardship Action Plan (Figure 4).
- Our initial research provides a pathway to identify a set of valuation metrics that better account for the non-monetary values of water that are critical to the sense of place and well-being of many NWT residents, particularly as they relate to subjective and relational dimensions of communities and individuals. Our focus has turned to identifying new metrics about social wellbeing (material, relational and subjective) that provide new insights on how people interpret and respond to changes in their environments (Table 2). It is not yet clear how to incorporate those values into policy and decision making processes that are relevant, for example in the context of the NWT Water Stewardship Strategy. This is key to enabling communities in the NWT to adapt to the impacts and cumulative effects of climatic and human activities on NWT waters, and the people whose well-being is tied to their environments.
- Findings from the ArcticNet project have illustrated how knowledge co-production processes that have evolved over time in the co-management institutional arrangements in the Arctic are triggering positive social and ecological outcomes in the face of environmental change (Armitage et al. 2011; Berkes and Armitage 2010). Results are also showing how art and artistic processes can be leveraged in innovative new ways to address adaptation challenges and improve institutional structures and processes which facilitate or constrain adaptation to changing conditions in Arctic communities.
- ArcticNet PhD student K. Rathwell is showing that art and artistic processes are playing an important role in several ways: 1) by bridging knowledge systems as they stimulate a new way of seeing the world, open space for multiple languages of expression, facilitate the creation of artistic boundary objects (objects that allow people from multiple perspectives to engage in dialogue about specific issues); 2) providing a visual basis to keep people connected during periods of rapid change as art and artistic

processes can help maintain emotional and social cohesion by guiding collective vision; and 3) facilitating adaptive management and adaptive governance by bridging knowledge systems and social cohesion which are processes that are sought after in adaptive co-management and adaptive governance mechanisms - adaptive co-management and adaptive governance may



Photo 1. "Sedna: life out of balance". 2006. Abraham Anghik Ruben (Inuvialuit, b. 1951), Brazilian soapstone; Collection of Peter and Belinda Priede (this sculpture uses a 'tipping' metaphor, offering a unique and intuitive perspective on the ideas of 'tipping points' in Arctic sea ice regimes).

be well supported by embedding art and artistic processes into decision making mechanisms.

- Initial insights suggest artistic processes, extended to the context of governance, could have a particularly rich resonance in the Canadian Arctic. Inuit capacity for the arts and imagery and forms of expression, such as oral history,

sculpture and song, are significant. Many of these art forms have been shown to reflect changes (environmental, social) and in a language that resonates with people. The implications for adaptation are significant but largely unaddressed. For example, the use of artistic processes to understand and navigate sea ice change in the Canadian Arctic provides new insights on how sea ice is changing and adaptation issues for a future Arctic (Photo 1).

### ***Adaptation to Multiple Forces: Mining in Baker Lake***

Climate change is recognized as just one of many external drivers of change in the Arctic, and resource extraction is clearly another key contemporary force. For researchers trying to make sense of possible impacts upon communities and possible adaptation options (consistent with the overall project objectives), one approach seeks to assess potential synergistic effects, as undertaken in the community vulnerability studies (e.g. Tuktoyaktuk, Ulukhaktuk, Hopedale). Another approach seeks to understand the implications of non-climate related drivers of change for a community's capacity to respond to changing climatic conditions. This latter approach has been adopted by research undertaken with the Hamlet of Baker Lake, which is proximate to Nunavut's only operating mine - the Meadowbank gold mine.

As supported by evidence from other mining jurisdictions, many individuals in the Hamlet of Baker Lake continue to benefit, at least financially, from their participation in local mining and its associated activities. For some, this additional income has enabled increased pursuit of traditional activities, and especially trips on the land, albeit using modern technology. As a community, however, the Hamlet continues to experience frustration with its inability to manage its experiences with, and capture benefits from, local mining given the institutional arrangements that empower the Kivalliq Inuit Association and disempower the Hamlet. This finding is consistent with mining and community health scholarship

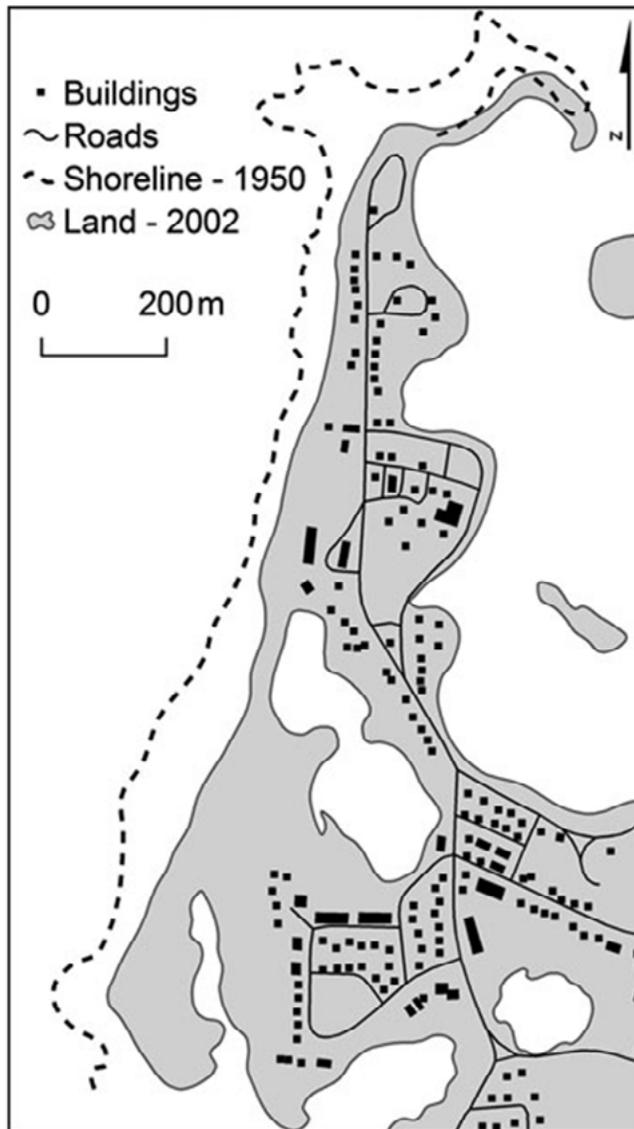


Figure 5. Locations of shoreline protection measures that have been implemented.

that highlights social determinants of health as the dominant vehicle through which contemporary mining impacts communities. For example, use of two-week rotational shifts can lead to feelings of stress, anxiety and depression, and impact one's personal interest in training opportunities. Mental health issues may also be connected to substance abuse; the need to stay alert during a shift, to decompress after a long stressful shift, or to connect with friends when back in the

community can result in higher substance abuse levels amongst rotational mine workers.

### ***Community Vulnerability and Adaptation in Tuktoyaktuk***

Environmental change in the Canadian Arctic has implications for livelihoods, food systems, infrastructure and Inuit culture. Although Inuit communities are located in industrialized countries, their integral connections with the natural environments contribute to significant exposures and sensitivities to changing conditions. Tuktoyaktuk in the western Canadian Arctic is susceptible to climate change in the context of ongoing socio-economic and environmental changes. Existing stresses in the community influence infrastructure, livelihoods, and wellbeing. Strategies for adapting to adverse conditions have largely been tactical and short term, rather than planned actions in anticipation of changes in climate. In light of projected intensification of climate change and a proposed natural gas pipeline in the Tuktoyaktuk area, the community is expected to experience new stresses in the future. Future adaptation planning and policy needs to enable community involvement in the protection of important community attributes.

This work contributed to all three project objectives. The initial step in the research process was to work with Tuktoyaktuk residents to identify current exposure-sensitivities. People in the community experience multiple stresses related to infrastructure and municipal services, livelihoods and local economy, and health and wellbeing. These exposure-sensitivities are dynamic and not exclusive of one another.

The locations of shoreline protection measures that have been implemented (based on personal observation, aerial photographs and Couture et al. 2002); locations indicated relative to the extent that they cover the shoreline; actual location of the material is on the shoreline and lines here are offset for emphasis (See Figure 5).

Table 3. Current Adaptive Strategies in Tuktoyaktuk.

Current exposure-sensitivities	Seasonal or year-to-year adaptive strategies	Permanent or long-term adaptive strategies
Risks for infrastructure and municipal services	Stockpile aggregate during winter months (for shoreline protection and to supplement protection under building foundations) Relocate/remove buildings with immediate damage risk	Shoreline protection (past: Longard tubes, sandbags; present: boulders, concrete slabs) Construction of inland road to gravel source
Stresses for livelihoods and local economy	Take advantage of (sometimes spontaneous) opportunities in subsistence harvesting or seasonal employment Seek employment outside of the community	Uptake of new technologies to make harvesting more efficient Management plans for protecting important species (e.g., protected areas for beluga whales; quotas or moratoriums on hunting species with declining populations)
Stresses for health and wellbeing	Shift location, timing and/or frequency of harvesting certain species Food substitution (e.g., switching to a different species or buying more store foods) Small entrepreneurial enterprises (e.g., tour operators, artisanal crafts)	Altered food preparation practices (e.g., more care during hot summer days; use of freezers to store meats)

Adaptation strategies employed in Tuktoyaktuk to deal with exposure sensitivities related to infrastructure and services, livelihoods and economy, and health and wellbeing are summarized in Table 3.

**Dynamic Vulnerability**

Sensitivities of Inuvialuit to changing environmental conditions and corresponding adaptive strategies evolve within dynamic arenas of economy, culture,

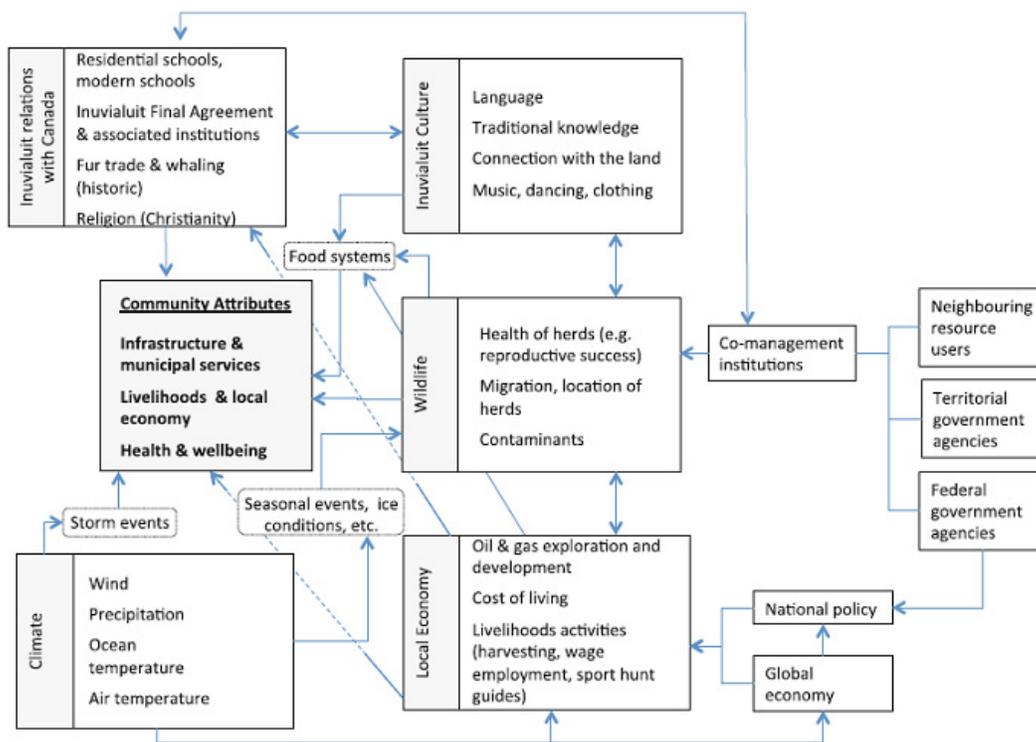


Figure 6. Relationships among elements influencing exposure-sensitivities in Tuktoyaktuk.

wildlife harvesting and climate that are inter-connected. While it is possible to distinguish particular exposure-sensitivities related to community attributes in Tuktoyaktuk, the forces and processes that influence them are interconnected. Interrelationships among elements that influence current exposure-sensitivities in Tuktoyaktuk are represented in Figure 6. For example, the Canadian government's imposition of standardized education and the introduction of new technologies have been linked to the erosion of traditional hunting skills (e.g., Ford et al. 2008; Pearce et al. 2011) and have contributed to the decline among youth in the pursuit of land-based livelihoods (or in the participate of traditional cultural activities such as drum dancing). Figure 6 traces how processes at multiple scales interact and influence vulnerabilities at the community level. For instance, co-management organizations link community leaders with federal and territorial government agencies and develop policies in response to climatic conditions and economic developments that influence the migration and health of wildlife and in turn play an important role in the success of harvesters (important for community livelihoods and wellbeing). As another multi-scale interaction, erosion has been a long-term factor for Tuktoyaktuk that has more recently been compounded by climatic changes. The ways that erosion has been addressed have largely been dictated by financial contributions from territorial and federal governments, which in turn are influenced by local and national economic conditions and shifting perceptions of the urgency of the problem. It is apparent that adaptations are motivated by these synergistic influences, rather than by climate alone.

The effects of climate-related changes and responses to them are greatly moderated by other forces of change in the community, some of which have considerable lags and non-linearities. For example, the residential school experience has influenced the language, traditional knowledge and connections with the land and southern culture over several generations of Inuvialuit. Current interest in traditional harvesting and in country food cannot be separated from these realities. While it would appear that with low employment there would be increased opportunities for harvesting activities for food

and income, the lack of experience and limited access to equipment are tied to time spent in school as youth, "dislocation" between generations and southern cultural influence on interest in harvesting activities (Pearce et al. 2011). All of these factors contribute to suppress wider engagement of the community in harvesting, particularly younger members of the community.

Clearly, the reported exposure-sensitivities and adaptive strategies are not found uniformly among all members in the Tuktoyaktuk community. As noted above, some residents, such as experienced hunters with the resources to maintain equipment, have adapted to changing environmental conditions by harvesting alternative species, whereas others have adapted by relying more on store-bought foods. Another example of differential vulnerability is in the area of residential property. Most community members in Tuktoyaktuk pay rent for their residences, but those who own houses near the high-risk erosion areas face greater risks. Thus, even among those community members with financial assets, there are disparities in exposures.

### *Future exposure-sensitivities*

Existing stresses faced by Tuktoyaktuk are expected to be exacerbated by climate change and the proposed Mackenzie Valley Pipeline. Of particular concern are changes in the abundance and distribution of wildlife since harvesters rely on many species as both a food source and source of income through sport hunting or sale of animal products. Infrastructure exposure-sensitivities will be heightened due to climate change. Risks associated with coastal erosion and flooding will be greater when there are longer openwater seasons and stronger storm surges occurring in the fall months. Permafrost instability may also become a greater concern since warmer air temperatures and a longer summer season will disturb the thermal regime of the permafrost that underlies Tuktoyaktuk.

Implications of climate change for future exposure-sensitivities are developed in Andrachuk and Smit (2012).

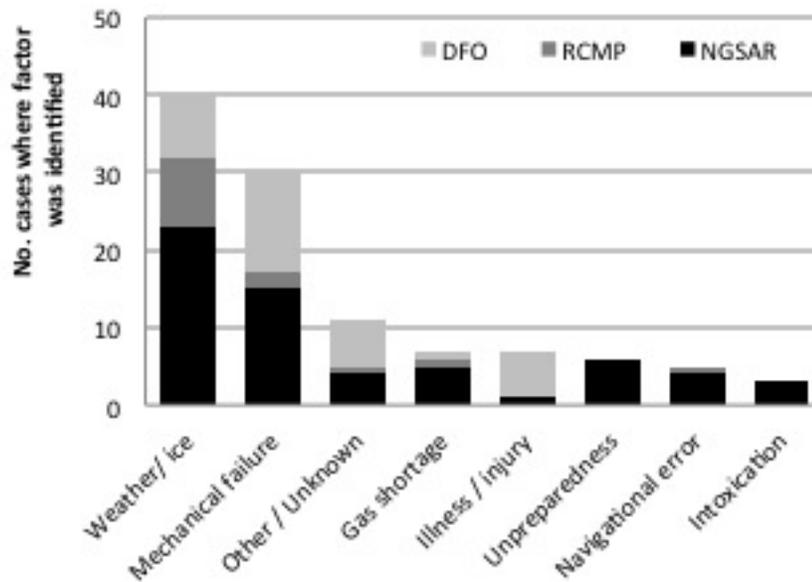


Figure 7. Average Annual Incidence Rate.

**Sea Ice, Inuit Health and Adaptation**

*The Role of the Environment in Search and Rescue (SAR) and Injury and Trauma*

Eighty-three SAR cases involving 218 individuals in the Nain area occurred from 1995 to 2010. Based on Nain population data and regional harvesting participation data, this represents an estimated average annual incidence rate of 19 individuals per 1000

requiring assistance through SAR. Weather and ice conditions were the most frequent contributing factor for cases (Figure 7). Ninety-six percent of cases in NGSAR and RCMP sources took place during the winter season when residents typically travel by sea ice. However, there were no temporal trends in the annual number of cases or the number of cases or individuals assisted during the winter season. The estimated incidence rate was six times higher for males than females, and travellers aged 26 to 35 had the

Table 4. Summary of references for expert travellers and representation of community members reporting on different forms of health and emerging themes related to place uses and experiences.

	References by expert travellers*	Representation of community members
<i>Forms of health</i>		
Mental / emotional	Some – primarily benefits, some impacts	All – primarily benefits, some impacts
Physical	Some – primarily impacts, few benefits	Nearly all – primarily impacts, some benefits
Economic / material	Few – some benefits, some impacts	Most – primarily benefits, some impacts
Social	Few – all benefits	Many – all benefits
Cultural	Few – all benefits	Some – all benefits
<i>Emerging place themes</i>		
Experiences of the sea ice as place	Many – all benefits	Nearly all – all benefits
Sea ice as a platform for hunting	Few – all benefits	Nearly all – all benefits

\*Scale for expert traveller references (n = 88) and community member representation (n = 22): few, 1-20%; some, 20-40%; many, 40-60%; most, 60-80%; nearly all, 80-100%

highest incidence rate among age groups. Twenty-one individuals sustained health impacts during winter travel in cases where health status was indicated, including three mortalities.

### *Sea Ice as a Determinant and Place of Health*

The majority of influences reported from using sea ice were positive health benefits spanning a variety of health aspects: mental/emotional, social, cultural, material, and physical health and wellbeing. A minority of influences were negative health impacts, primarily related to physical health, and to a lesser extent mental/emotional health and material wellbeing (Table 4). Some of the highest response rates were on themes related to ‘place’ meanings and experiences: i) importance of sea ice as a platform for hunting, and ii) meaning of sea ice as freedom.

### *Factors Mediating Health Influences of Environmental Exposure*

Differences in reporting frequencies and themes in terms of health influences of sea ice use were based on gender, age, sea ice travel experience, frequency of hunting or fishing, and ability to speak Inuittitut. Participants also reported on the impacts of socio-cultural change on sea ice travel practices and knowledge

### *Risk Perception of Sea Ice Users*

Ice and weather conditions were the primary factors reported as contributing to difficult/unsafe trips, while knowledge and support, places travelled and experiences of those places, and activities undertaken were factors reported as contributing to good/safe trips. Differences in reporting were based on gender and years of sea ice travel experience (e.g., expert travellers identified a wider range of environmental conditions than community members). Changes in safety were reported by nearly all participants, with many reporting that travel is more dangerous today because of changes in ice and weather conditions.

### *Environmental Health Risk Management and Climate Change Adaptation*

Risk-benefit management processes involved long and short-term strategies comprising of travel skills, knowledge gathering and sharing, preparing, and managing ‘trouble events’. Differences in application of strategies primarily varied according to years of travel experience, and to a lesser extent gender. Some adjustments to strategies associated with changing environmental conditions were reported, including increased knowledge gathering and sharing by very experienced travellers, and increased preparation and risk avoidance among some sea ice users. Importance of informal support and community-based SAR for managing trouble events, and overall positive perception of SAR in the community were reported. However, most participants reported the need to improve community health and safety for sea ice travel.

The Nunatsiavut Sustainable Communities Initiative conducted five workshops in the winter and spring of 2012-13. In those communities, discussions around five key themes were identified related to community sustainability around which adaptation support / solutions were required. They included: Infrastructure, housing and community development, valued spaces and places; Energy security; Food security; Transportation and emergency services; and Safe communities (Goldhar et al., 2012).

## **Discussion**

### *Knowledge accumulation and transmission*

The ability of an individual to draw on IK to adapt to changing conditions depends on if, and to what degree, IK has been transmitted. In this context, transmission refers to the process of transferring a cultural item, such as a skill or locally-specific piece of knowledge, among individuals through participation and experience in an environment and where transmission success depends on the level of mastery of a particular

item (Ohmagari and Berkes, 1997; Ingold, 2000; Pearce et al., 2011). Traditionally, skills among Inuit were developed and transmitted hands-on through on-the-land education, and from listening to and learning from Elders and other experienced individuals (Condon, 1996; Takano, 2004; Barnhardt and Kawagley, 2005; Pearce et al., 2011). In their study of skills transmission among Inuit men in Ulukhaktok, Northwest Territories, Pearce et al. (2011) confirm that the traditional modes of skills transmission, observation and apprenticeship, continue to function today, albeit to varying degrees of success across the population. Some skills have been lost, some are being transmitted incompletely or to elementary levels, and others are new skills (e.g. navigate using a GPS, read a weather report, start and tend a naptha stove, etc.) that the older generation did not possess but are currently being widely adopted (Berkes and Jolly, 2002; Ford et al., 2006; Pearce et al., 2011).

This ‘deskilling’ is linked to a gradual disengagement of younger generations from the land and subsistence activities, beginning with the settlement of Inuit in communities starting in the late 1950s and accelerating over subsequent generations. Disengagement from the land and subsistence activities has been linked to several factors including: requirements of formal schooling, increased dependence on wage employment, alternative activities (e.g. sports), increasing intergenerational separation between young and older generations, new technologies (e.g. Internet, video games, television, social media), a decline in the prestige of being a hunter, and the desire among youth to follow ‘western’ rather than ‘traditional’ social norms (Condon et al., 1995; Collings et al., 1998; Ford et al., 2006). In addition, Pearce et al. (2011) identified the presence of a ‘teacher,’ a father or grandfather, as a key factor influencing the transmission of knowledge and land skills among young Inuit men. Respondents who had a father or grandfather as a teacher had learned the most skills, at the earliest ages, and to the most advanced levels. In contrast, skills transmission was lowest among respondents who did not have a father in their lives.

In light of these and other factors, Inuit leaders and northern representatives acknowledge the need for institutional support to assist in strengthening the transmission of IK among younger generation Inuit, particularly among marginalized community members. Several programs have been initiated in Inuit settlements across Canada and include, land camps which involve groups of young Inuit traveling with Elders and other experienced individuals to traditional camping grounds to learn hunting, fishing, traveling and camp-related skills; school-led on-the-land trips, often day-trips together with Elders and other experienced individuals; skills-training at local schools or in the community, including sled-building, skin cleaning, fur preparation, and traditional clothing sewing; and on-the-land training for Inuit youth offered through the Canadian Rangers (a division of the Canadian Armed Forces) through the Junior Rangers program (Pearce et al., 2011). The degree to which IK is evident in these programs varies. In the context of academic schooling, Laugrand and Oosten (2009) and others (Stairs, 1992; Rasmussen, 2001) challenge the notion that IK can be effectively integrated into current Eurocentric academic programming arguing that the school system should be adapted to meet Inuit perspectives rather than the reverse.

Institutional programming clearly does not replace traditional methods of knowledge transmission through observation and apprenticeship; it does, however, provide some Inuit youth – many who would otherwise not have the opportunity – to participate in subsistence and gain exposure to skills teachers and mentors. It is important to note that skills training does not have to be limited to schools, but can be supported through a variety of local and regional organizations and structures. For example, a new program underway in Nain, Nunatsiavut called Aullak, sangilivalliinginnatuk, brings together Inuit youth and experienced hunters to improve a community freezer program. Youth participate in subsistence activities and learn the values and benefits that traditional foods, and the sharing of these foods, provide to them and their families, and generate a source of meat for the

community freezer. Through this process, youth also have the opportunity to connect with adult mentors in the community, and to develop relationships with those who are still active on the land and are willing to transmit skills and IK. Similarly, the newly established cultural school, Piqqusilirivvik, in Clyde River, Nunavut is dedicated to enabling the transfer of traditional culture, knowledge, life style, skill sets and values, taught in the Inuit language and based on Inuit Qaujisarvingat guiding principles.

### ***Adaptive Capacity for Addressing Future Changes in Tuktoyaktuk***

Adaptive capacity is related to the ability of (in this case) a community's potential or ability to moderate potential damages, take advantage of opportunities, or cope with the consequences of climate or other changes (Smit & Pilifosova 2001; Yohe & Tol 2002; Brooks & Adger 2005). Analysis of current responses to changing socio-economic and environmental conditions indicates that within Tuktoyaktuk there is considerable capacity to deal with intensification of existing exposure-sensitivities, although adaptive capacity is highly variable. In light of continual adjustments to harvesting practices, economic opportunities, and social conditions over the last century, Inuvialuit in Tuktoyaktuk are accustomed to change and have experience with facing unprecedented circumstances.

*This community has been adaptive enough to meet the needs of whatever comes. And historically, our ancestors were able to do the same thing. Being ready for it and being prepared for it and taking advantage of it when it does come I think reflects on the lifestyle we've been able to be comfortable with. We go with the flow.*

- Eddie Dillon, Tuktoyaktuk resident

People who are able to take advantage of opportunities in both the wage economy and subsistence harvesting have flexibility and the greatest capacity to adapt to changing economic and environmental conditions. These people draw upon strong cultural heritage and demonstrate flexibility and willingness to

innovate. In contrast, people who do not participate in subsistence harvesting have fewer options for obtaining food and other necessities when they are unable to secure employment. Issues surrounding substance abuse and decline in social cohesion within the community further exacerbate these constraints. There are indications that there is less trust within the community and that sharing networks are less reciprocal than they were in the past. The implication of these issues is that some Tuktoyaktuk residents face considerable constraints in dealing with current and future exposure-sensitivities related to livelihoods and food security. There are currently no institutions within the community that deal with this full suite of issues. Some financial assistance and opportunities for skills development are available through the Community Corporation, but this organization does not have a broad mandate for systematically addressing issues such as substance abuse, and it has a limited ability to generate employment opportunities.

In the context of international climate policy, Arctic communities fall under the provisions of developed nations, despite living in conditions similar to many developing nations. While the Arctic has enjoyed a raised profile in recent years, Canadian Arctic residents still do not command the same political clout or have access to a similar level of services and resources as their southern counterparts. These realities are reflected in basic social, housing and economic needs that are not met in many instances, let alone the provision of resources for planning and preparing for adaptation to risks posed by climate change. The resources that have been provided by the federal government tend to be directed towards Canadian sovereignty, security and research, with less attention to community needs and challenges. In particular, Canada's Auditor General has reported that the federal government has not shown consistent commitment to the needs of Northerners and has not followed through with their responsibilities under the Inuvialuit land claim settlement (Auditor General of Canada 2007).

Addressing risks to infrastructure and buildings due to permafrost degradation, flooding, and coastal erosion

are generally beyond the capacity of the community due to financial and technical constraints. Individuals and families do not have the resources to protect the shorelines or relocate their property. Although the municipal government is the institution responsible for maintaining infrastructure, they do not hold the financial resources required for addressing these risks in a comprehensive way. They are entirely dependent upon funding, approval, and support from territorial and federal government agencies. Given the sensitivity of infrastructure that will be exacerbated by climate change, and the limitations of adaptive capacity, this is a key area of future vulnerability for Tuktoyaktuk.

A proposed extension of the inland all-weather road from Tuktoyaktuk to Inuvik would have several benefits for the community, including increased ability to adapt to shoreline erosion and risks to buildings and infrastructure (alleviating some technical and financial constraints). Advocates of the all-weather road also believe that the road would open up the community for new economic opportunities and enable more affordable transportation of food and goods into the community. Indeed, increased land connection to Tuktoyaktuk would alleviate some constraints to adaptive capacity by lowering the cost of food and supplies and generating new opportunities for tourism and employment.

### ***Adapting to Multiple Stresses: Mining and Baker Lake***

The Hamlet of Baker Lake is the only community in Nunavut proximate to an active mine. This is creating new challenges and opportunities, and is forcing the Hamlet to focus on issues that are less pertinent in other communities. Though the impacts of climate change, and resulting community vulnerabilities, are similar to other Arctic communities, the community's attention to climate change is arguably more modest; Baker Lake has become a 'mining town' and this dominant activity dominates Hamlet governance. At the community scale, there is little evidence that mining is augmenting adaptive capacity; indeed the institutional arrangements that govern mine

development have added to historical processes of disempowerment. At the individual scale, however, there is considerable evidence of augmented capacity largely as a result of increased household incomes.

Engaging residents of the Hamlet of Baker Lake in discussions of climate change adaptations is challenging. The primary issue in the community, on which residents focus when communicating with outside researchers, is the impact of the Meadowbank gold mine and the possible impact of Uranium mining as currently proposed by Areva Resources. The project has achieved great success in engaging residents on this topic through interviews, focus groups, community gatherings, and call-in radio programs.

### ***Knowledge Co-Production, Place Identity and Governance in Adaptation***

Our research has helped to shift the conversation away from knowledge 'integration' and towards a more holistic focus on knowledge co-production, defined as the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem as it pertains to Arctic change. We have shown how knowledge co-production is an institutional trigger or mechanism that enables learning within co-management settings in the Canadian Arctic, thus creating opportunities for more effective adaptation. Importantly, we have extended the emphasis beyond conventional ideas of what is knowledge (data, information, reports) to include art and artistic processes. These forms of knowledge engage communities and can link scientists, policy makers and communities in promising and innovative new directions for adaptation research.

The importance of place identity in framing adaptation perceptions and options, and in supporting social wellbeing (particularly where that wellbeing is connected to water resources), has emerged as a crucial dimension of adaptation. Our focus on identifying new metrics of social wellbeing (material, relational and subjective) is providing new insights into how people

interpret and respond to changes in their environments. This is a particular concern in a rapidly changing Arctic, and it remains a crucial need to determine how place, well-being and knowledge co-production involving communities and hunters, scientists and managers can be used to inform policy. A social conception of well-being and understanding of how people are connected to places (using water resources as a focal example because of the cultural importance of water) illustrates how northern communities are simultaneously embedded within and acting as agents of change (positive and negative). The cases examined through ArcticNet help to illustrate the institutional mechanisms through which co-management actors can learn to learn, or learn to be adaptive, and the contextual (subjective) factors that are important to those institutional processes.

Climate change will redefine the relationships people have with place and influence their wellbeing. Our research is helping to articulate those relationships people have with place and the role of such relationships in adaptation. The inclusion of subjective factors in understanding and addressing individual and community-level experiences of climate change is crucial. Clarity on the role of place, wellbeing and knowledge (in its many forms, such as art and artistic processes) facilitate climate change adaptation and offer avenues to build adaptive capacity.

We are showing that adaptation strategies must be embedded in more collaborative and adaptive policy and governance contexts. Across Canada's North, institutional and policy conditions are evolving: (1) collaborative governance mechanisms are evolving to supplement regulatory mechanisms but questions of fit among these various mechanisms still need to be answered, especially given the realities of biophysical and socio-economic change; (2) networks of policy/governance and community actors have emerged but sustaining these formal and informal governance networks is an ongoing requirement; (3) the knowledge needed to deal with complex social-ecological systems takes different forms (e.g., scientific and local) and is held by actors outside of governments. It is important to

recognize that non-scientists are knowledge generators as well as knowledge recipients.

### ***Sea Ice, Inuit Health and Adaptation***

Results from this study of the relationship between sea ice travel and Inuit health demonstrate how sea ice use results in a complex array of health impacts and benefits; ways that Inuit manage the risks inherent with this activity; which factors mediate health influences of sea ice use; and how Inuit are perceiving and adapting to changing environmental conditions.

Specifically, results demonstrate that environmental influences from sea ice use contribute to physical health risk in Inuit communities and that age and gender are important risk factors for SAR events and land-based injury and trauma. These results improve our knowledge of the role of environmental influences on injury and trauma for Inuit. Results also document the complexity of health impacts and benefits from sea ice use for a variety of health aspects, and the health determinants (e.g., gender, employment status, frequency of environmental use, etc.) that influence the distribution of health impacts and benefits from sea ice use. This understanding addresses objectives 1 and 2 of this study in incorporating both Inuit knowledge and science in assessing vulnerabilities and understanding the role of institutions (in this case institutional Search and Rescue organizations) in facilitating adaptation. Results on sea ice travel being more dangerous now compared to the past corroborate other studies which document observations by Inuit of increasing unintentional injuries due to changing environmental conditions (e.g., Furgal et al., 2002; Nickels et al., 2006). Results also document strategies used to manage sea ice related risks and benefits and adapt to changing conditions, and demonstrate that gender and years of travel experience influence the strategies used to adapt to changing conditions. These results corroborate and add to our understanding of climate change adaptation, and can be used to inform interventions aimed at strengthening the capacity of individuals in northern communities to maximize benefits and minimize risks associated with sea ice use.

## Conclusion

Overall, the components of this project have made significant progress in documenting and explaining the changing physical, biological and socio-economic conditions that are affecting people in the Arctic and in identifying the policies and strategies to assist communities in dealing with these changes. The researchers have undertaken their analyses of the dynamic forces affecting Arctic communities via collaborations and partnerships with northern people and organizations. Case studies provide a wealth of information on the nature of change in the Arctic and the vulnerability and resilience of Arctic people, manifested in a broad range of adaptive strategies relating to health, infrastructure, knowledge transmission and integration, management arrangements, safety of travel on sea ice, access to country foods or community well-being.

The applied research initiatives (individually and cumulatively) have substantively addressed the three project objectives:

- integrate natural and social science and Indigenous Knowledge in vulnerability assessments;
- examine the institutional structures and processes which facilitate or constrain adaptation to changing conditions in Arctic communities;
- engage northern communities in assessments of adaptation strategies and options.

This project has provided insights beyond physical and biological impacts of climate change by assessing the sensitivities of northern peoples' lives and livelihoods to rapid changes, and by integrating local and traditional knowledge with scientific knowledge for a comprehensive and locally-relevant understanding of socio-economic and natural processes and interactions in the North. It has demonstrated that communities are susceptible to-and adjusting to-a variety of dynamic conditions, with social, political and economic forces interacting with physical and biological forces. It has

also demonstrated that "adaptation" takes many forms, is rarely with respect to climate change alone (if at all), and involves transformation of learning, knowledge and behaviours among individuals, communities and institutions.

This project has generated research results that are significant for the future of Arctic communities across the Canadian North. Future research that fosters integration and cross region comparisons and lessons, will ensure practical relevance of the research as well as the necessary follow up, detailed analysis and dissemination with our research partners across the North in the face of an increasingly changing northern environment.

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