Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada

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Abstract

This paper develops a vulnerability-based approach which is used to characterize the human implications of climate change in Arctic Bay, Canada. It focuses on community vulnerabilities and the processes through which people adapt to them in the context of livelihood assets, constraints, and outside influences. Inuit in Arctic Bay have demonstrated significant adaptability in the face of changing climate-related exposures. This adaptability is facilitated by traditional Inuit knowledge, strong social networks, flexibility in seasonal hunting cycles, and institutional support. Changing Inuit livelihoods, however, have undermined certain aspects of adaptive capacity, and have resulted in emerging vulnerabilities in certain sections of the community.

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1. Introduction

The Arctic Climate Impact Assessment (ACIA) has predicted that future climate change will be experienced earlier and more acutely in the polar regions (Hassol, 2004; Kattsov and Kallen, 2005). These changes will occur on top of recent climate change, which has been documented by instrumental records and indigenous observations in the Arctic (Huntington and Fox, 2005; McBean et al., 2005). There is general agreement that indigenous peoples in the North are being affected by climate change and that future changes in climate are likely to pose serious challenges. However, the nature of these risks is poorly understood and assessing vulnerabilities was recently identified by the ACIA as a major area where further research is required (Hassol, 2004; McCarthy and Martello, 2005).

This paper presents an approach to characterize the nature of vulnerability to climate related conditions in Arctic communities. The approach focuses on how people experience, respond to, and cope with environmental phenomena, in the context of livelihood assets, constraints, and outside influences. The approach is applied in a case study of the Inuit community of Arctic Bay, Canada. Findings indicate that Inuit in Arctic Bay have demonstrated significant adaptability in the face of changing climate-related exposures. Changing Inuit livelihoods, however, have undermined certain aspects of adaptive capacity, and have resulted in emerging vulnerabilities in certain sections of the community. Analysis of current vulnerability indicates that vulnerability to future climate change will differ between social groups, will be influenced by livelihood conditions, and according to the nature of climate change. The paper begins by evaluating the nature of the problem posed by climate change in the Arctic, and reviews existing research on the human dimensions of climate change in the Arctic.

2. Climate change in the Arctic

There is evidence that climate change is already occurring at high latitudes (Hassol, 2004; McBean et al., 2005). Over extensive land areas, significant warming, increased precipitation, alterations in sea ice dynamics, and a change in climatic variability and the occurrence of extremes, have been recorded by instrumental records and indigenous observations (Krupnik and Jolly, 2002; Helander and Mustonen, 2004; Johannessen et al., 2004; Huntington and Fox, 2005). These changes are posing significant risks and hazards to communities throughout the circumpolar north. Indigenous residents have expressed growing concern (NTI, 2001; Bell et al., 2002; Simon, 2004). Many of these risks are associated with subsistence activities. In traditional northern communities, people spend significant time hunting and travelling on the land (Aporta, 2004) and rely on livelihoods that are being affected by climate change. For Inuit hunters in Canada's Nunavut Territory, climate change has meant that their traditional knowledge, which underpins safe and successful hunting, is less dependable (Ford and Smit, 2004). In the small Inuit community of Kugluktuk, for example, unusual ice conditions have been linked to the deaths of two residents who went through the ice on a snowmobile in 2004 (CBC, 2004). The changes have also made access to hunting areas increasingly difficult. Reduced water levels in rivers and lakes near Baker Lake, Nunavut, have restricted travel and access to hunting grounds (Fox, 2002). Other risks are associated with infrastructure. Throughout the Arctic,

coastal erosion and retreat, and melting permafrost have damaged infrastructure and cultural heritage sites (Shaw et al., 1998; Couture et al., 2002; Nelson et al., 2002).

Future climate change is predicted to be experienced earlier and more acutely in the polar regions (Holland and Bitz, 2003; Hassol, 2004; Kattsov and Kallen, 2005). Predicted changes include: increased temperature and precipitation; alterations to the frequency, magnitude, and geographic distribution of climate related events; reduced areal extent and thickness of the sea ice and permafrost; and a reduction in the number animal species (Houghton et al., 2001; Kerr, 2002; Derocher et al., 2004; Johannessen et al., 2004; Kattsov and Kallen, 2005). Even under the most aggressive emission control measures, current greenhouse gas emissions commit the earth to continued climate change (McBean et al., 2001; Metz et al., 2001; Hansen et al., 2002). The likelihood of adverse impacts has created a growing urgency to improve understanding of how indigenous peoples in the Arctic will be affected by these changes, and how they might deal with, or adapt to them (Nuttall, 2001; Duerden, 2004; Ford and Smit, 2004).

3. Human dimensions of climate change in the Arctic

Much of the information on the implications of climate change for communities in the Arctic is in the form of broad studies conducted by government agencies (Cohen, 1997) and reviews in the IPCC's Third Assessment Report and the Arctic Council's ACIA (Maxwell, 1997; Anisimov and Fitzharris, 2001; Hassol, 2004). Information is also available from specific studies of the implications of changes for certain biophysical systems (Shaw et al., 1998; Nelson et al., 2002). These studies have focused largely on predicting how certain biophysical systems are being affected by, and will respond to, climate change.

While this research has increased our understanding of how climate change will affect biophysical processes, our current level of knowledge about its implications for human activity and societies remains limited (Duerden, 2004). The consequences of a shift in climate for humans are not calculable from the physical dimensions of the shift alone; they require attention to human dimensions through which they are experienced (Rayner and Malone, 1998). People have learned to modify their behaviour and their environment to manage and take advantage of their local climatic conditions over the course of human history (Adger, 2003a). Research has shown that indigenous groups in the Arctic have historically demonstrated adaptability and resilience in the face of changing conditions (Balikci, 1968; Sabo, 1991; Cruikshank, 2001).

Much of the work on climate change in the Arctic focuses on climate in isolation from other conditions which influence the implications of climate change for communities. The way in which people experience, respond to, and cope with environmental phenomena occurs in the context of social, cultural, economic, and political conditions and processes (Blaikie et al., 1994; Bohle et al., 1994; Thomas and Twyman, 2005). In the Arctic, there have been dramatic changes in livelihoods in the latter half of the twentieth century (Bone, 1992; Condon et al., 1995; Nuttall, 2000; Fenge, 2001; Csonka and Schweitzer, 2004), which have affected many of the traditional mechanisms by which Inuit communities manage climatic conditions.

Livelihood changes are predicted to continue and further alter Inuit communities and well-being (Fenge, 2001).

There has also been limited research incorporating community perspectives on the human implications of climate change. For Arctic communities, many risks are associated with harvesting activities. The changes that people identify as being important are those which affect their safety while harvesting or their ability to harvest (Fox, 2002; DSD, 2003; Fox, 2004). Assessing the vulnerability of Arctic communities to climate change requires documentation of climate related conditions that are relevant to people, how they affect people and their livelihoods, and the management strategies they employ.

4. A vulnerability based approach

4.1. Conceptual model of vulnerability

The 'vulnerability approach' has evolved in the field of climate change impacts and adaptation to address the research needs highlighted above (Kelly and Adger, 2000; Burton et al., 2002; Smit and Pilifosova, 2003; Ford and Smit, 2004). The conceptual model of community vulnerability outlined here (Fig. 1) draws on this scholarship and also the natural hazards, environmental change, and development literature (White, 1974; Hewitt, 1983; Blaikie et al., 1994; Adger and Kelly, 1999; Pelling, 1999; Turner et al., 2003). It conceptualizes vulnerability as a function of exposure-sensitivity of a community to climate change effects and its adaptive capacity to deal with that exposure.

One central element in the model, exposure-sensitivity, reflects the susceptibility of people and communities to conditions that represent risks, including those associated with climate change. Exposure-sensitivity is dependant upon both the characteristics of climatic conditions, and the nature of the community in question. The characteristics of climate-related conditions include magnitude, frequency, spatial dispersion, duration, speed of onset, timing, and temporal spacing of conditions. The nature of the community concerns its location and structure relative to the climatic risks. It is also strongly linked to livelihood conditions and strategies and will vary among groups in the community. In Arctic communities, different species will be harvested in different locations at different times of the year on account of individuals' knowledge of the environment, past experience, differential time constraints, and access to technology. This results in differential exposure-sensitivity. Exposure-sensitivity is clearly dynamic, changing as the community changes its characteristics relative to the climatic conditions, and changing as the stimuli themselves change. It also reflects human and biophysical conditions and processes operating at broader scales, which elsewhere called 'root causes' (Blaikie et al., 1994), 'external drivers' (Folke et al., 2003), or 'influences acting on place' (McCarthy and Martello, 2005). Social and economic changes, for example, filter through the particular attributes of groups or individuals to influence decisions such as where to hunt, what to hunt, when, and what equipment is taken along. Climate change interacts to affect the characteristics of climate related conditions, changing the nature of the potential risks posed.

Adaptive capacity (Fig. 1) refers to a community's potential or ability to address, plan for, or adapt to exposure-sensitivity (Smit and Pilifosova, 2003). People have learned to modify their behavior and their environment to manage and take advantage of their local climatic conditions. Most communities, therefore, are adaptable to normal climatic conditions and a range of deviations around norms (Ford and Smit, 2004; Tompkins and Adger, 2004). This ability to adapt reflects resource use options and risk management strategies to prepare for, avoid or moderate, and recover from, exposure effects (Hewitt and Burton, 1971; Smit et al., 1999; Jones, 2001; Smit and Pilifosova, 2003). It is influenced by characteristics of the human system including economic wealth, social capital, infrastructure, social institutions, experience with previous risk, the range of technologies available for adaptation, and equality; these may facilitate or constrain the ability of a community to deal with climate related risks (Handmer et al., 1999; Barnett, 2001; Adger, 2003a; Smith et al., 2003; Robards and Alessa, 2004). These determinants are interdependent and are influenced by human and biophysical conditions and process operating at various scales from the local to global**.** Adaptive capacity is also dynamic, varying over space and time with the characteristics of the human system.

Exposure-sensitivity and adaptive capacity are not mutually exclusive (McLeman and Smit, 2005). Exposure to repeated climate-related conditions, for instance, develops experience of how to manage the climatic condition and enables 'response with learning,' thus increasing the adaptive capacity of the system (Gunderson and Holling, 2002). Alternatively, certain adaptive strategies change the nature of the community (location, structure, organization) such that the community is less exposed-sensitive, or more exposed-sensitive, or exposed-sensitive in a different way. Note also that the factors that influence adaptive capacity also influence exposure. For example, the range of technologies available for adaptation may enable exposure to be managed. The same technology, however, may also affect risk evaluation strategies and result in more risk taking behaviour.

4.2. Analytical framework

The model of vulnerability recognizes that exposure-sensitivity and adaptive capacity of communities are continually influenced by social and biophysical conditions and processes operating at various scales. The experience of, and response to, future climate-related exposures will be facilitated and constrained by similar, if not the same, factors (Glantz, 1988, 1996; Adger and Kelly, 1999; Adger, 2003a; Naess et al., 2005). To learn about how future climate change may affect communities, the starting point here is the present and the past, in order to identify those conditions that are significant for the community and to establish a baseline as to how the community deals with them. The analytical framework follows Ford and Smit (2004). The first stage starts with the community itself, incorporating the knowledge and observations of local residents to assess current vulnerability by documenting current exposure-sensitivities and current adaptive capacity. The second stage assesses future vulnerability by estimating directional changes in exposure-sensitivity and assessing future adaptive capacity on the basis of past behaviour and identification of future adaptation options, constraints, and opportunities. This paper applies the framework in the community of Arctic Bay, Nunavut.

5. Arctic Bay Case Study

5.1. Arctic Bay

Arctic Bay is a coastal Inuit community of 646 people located on north Baffin Island, Nunavut, Canada, approximately 700 kilometres north of the Arctic Circle (see Fig. 2). Ninety-three percent of the population is Inuit (StatsCanada, 2002). The settlement has expanded dramatically since the 1960s, and the economy has shifted from one based entirely on subsistence activities to a mixed economy where both the informal and formal economic sectors assume an important role (Damas, 2002). Hunting underpins the social, cultural and economic fabric of the community and contributes significantly to the food supply (Reeves, 1993; NWMB, 2001; DSD, 2002). Narwhal, ringed seals, arctic char and caribou are the mainstays of the wildlife harvest in Arctic Bay. Except for a period of open water from mid July and early October, travel and harvesting is largely performed on sea ice. Considerable time is spent by most community members 'on the land,' (a term used by Inuit to refer to any traditional activity (hunting, camping, or travelling) that takes place outside the settlement).

5.2. Methods

Sixty-five semi-structured interviews were conducted in 2004 to identify those conditions and risks that people have had to deal with, and are currently dealing with; to provide insights into the resource use options and risk management strategies employed to manage these conditions; and to identify those factors that influence the ability to manage risks. The data collection was undertaken with two Inuit assistants. Interviews were conducted in Inuktitut and English with the majority taking place in the homes of interviewees, although some were undertaken at summer camps 'on the land.' For preliminary verification and validation, after each interview the key points raised were reviewed with the local assistants. The interviews were complemented with experiential trips with Inuit on the land and informal meetings with key informants. Analysis of secondary sources, including government reports, newspaper articles, books, and journal articles, was used to add historical context on risks and adaptation. A second field session was undertaken in early spring 2005. The results and interpretation from the first field session were evaluated and reviewed with people interviewed during the first trip.

6. Current Vulnerability

6.1. Changing exposure-sensitivity

In Arctic Bay, a combination of changing climatic conditions and changes in livelihoods increased the exposure-sensitivity of the community to climatic risks. The majority of community-identified exposure-sensitivities documented in this research are associated with harvesting activities. Others are associated with community infrastructure (roads, houses, sewage system) and health, although to a lesser extent.

6.1.1. Changing climatic conditions

The interviews indicate a perception of changing climatic conditions since the early to mid-1990s. These changes, along with changes in livelihoods documented in the next section, have amplified the magnitude and frequency of hazardous conditions that

people have to deal with. This has had implications for safety while hunting and travelling, particularly during sea ice freeze-up and break-up. Before going out on the land, hunters will typically look at the clouds, including their height, form, and the direction they are moving. This information, as well as observations of wind direction and other environmental conditions, are used to forecast the weather, decide if it is safe to go out, and identify precursors to hazardous events. Prediction is essential; the ability to anticipate and respond to dangers, opportunities, and changes, is important for safe travel. Strong winds, for example, can be dangerous while boating on open water in the summer, can cause whiteout conditions in the winter, and can rapidly disintegrate the ice during sea ice break-up. The traditional knowledge used to make predictions, however, has become less dependable as the result of changing climatic conditions and has made hunting more hazardous (see Table 1).

> "Nowadays my traditional knowledge, I can't use [this] knowledge now," – Lisha Levi, Arctic Bay

> "More lives are in danger because of these unpredictable conditions [and] change[s]," – Leah Kalluk, Arctic Bay

Changing climatic conditions are having implications for the accessibility of resources. Community access to hunting areas from October to July depends on the condition of the sea ice and snow, and in summer on the state of inland trails and the ability to use boats. Thin snow cover on the land in winter is restricting access to inland caribou hunting by snowmobile. Hunters have damaged snowmobiles and sleds while travelling on trails where the snow was thin. Later and longer ice freeze-up is changing the timing at which harvesting can take place. Harpoon seal hunters and ice fishers have to wait longer before they are able to travel on the ice. In summer, melting permafrost is making trails to inland caribou grounds extremely muddy. Other changes are affecting accessibility by making travel dangerous. Stronger and more unpredictable winds are also limiting access to hunting grounds by boat in summer; the small boats used locally do not offer protection in rough water.

> "The wind and the waves is preventing the hunters from going to and from the hunting grounds," – Koonoo Oyukuluk, Arctic Bay

The changes in accessibility have important ramifications for the community as locally harvested animals and plants (known as 'country food') have a significant social, cultural, and economic importance (Pratley, 2005).

6.1.2. Changing livelihoods

There have been dramatic changes in Inuit livelihoods in the last half of the twentieth century as a result of the transition of a traditional subsistence Inuit lifestyle to a 'dual society' or 'mixed economy' characterized by the co-existence of a market and traditional sector (Wenzel, 1991; Condon et al., 1995; Berkes and Jolly, 2002; Damas, 2002; Chabot, 2003; Csonka and Schweitzer, 2004). Associated with this transition has been settlement of semi-nomadic groups in centralized permanent villages, increasing importance of the federal government in people's lives, the development of formal economic sector activities, participation in, and dependence on, external markets, and compulsory schooling for children. The following examples illustrate

how these broader developments associated with changing livelihoods have compounded the problems caused by changing climatic conditions to increase exposure-sensitivity to climate-related risks in Arctic Bay.

As a result of government promotion of fixed settlement in the 1960s hunters found their spatial access and associations with their traditional resources considerably altered (Damas, 2002; Wenzel, 2004). This resulted in the increased use of, and dependence on, imported technology such as snowmobiles and motorized boats; these are used to travel beyond the limited zone of exploitation imposed by fixed settlement (Wenzel, 1991; Condon et al., 1995; Wenzel, 1995, 2004). A corollary of this has been a progressive replacement of dog teams with snowmobiles. The use of snowmobiles requires knowledge of where the safe and unsafe ice is located, because, unlike dog teams, snowmobiles cannot locate and avoid dangerous ice. Interviewees talked about the dangers of snowmobile use; since their introduction, there have been incidents where hunters have been unable to identify ice thickness, and have gone through thin ice. From personal observation and experience, hunters have managed these risks by knowing the location of dangerous ice and times of the year to be careful. With increasingly unpredictable ice conditions, however, snowmobile travel has become even more risky.

Modern hunting requires substantial monetary investments and has resulted in increased dependence on monetary resources (Chabot, 2003). Traditionally, hunters supported themselves almost exclusively from hunting and trapping, trading skins and furs for equipment (Wilkinson, 1955; Freeman et al., 1998; Damas, 2002). Increased prices of equipment combined with declining markets in Europe for seal skins (Wenzel, 1991), however, have resulted in hunters seeking to secure an income from different sources to support their harvesting activities, including the commercial exploitation of narwhal for the tusk ivory. At the same time, government quotas on narwhal limited the catch of this commercially important species (Kemper, 1980). As a result of these two trends, hunters have attempted to maximize their chance of catching narwhal before the quota expires by hunting them as soon as they arrive in the region. This usually occurs during June and July from the edge of the ice that is anchored to the shore (known as the floe-edge) when the ice is breaking up. Traditionally, hunters would have avoided this time, waiting for the narwhal to migrate closer to the community where they can be hunted close to the shore and safely (Wilkinson, 1955; Brody, 1976; Kemper, 1980; Freeman et al., 1998). The floe-edge is a highly unstable environment (MSC, 2004) and break-up is the most dangerous time to be on the ice.

> "The people want to get [a] fast buck, they start going out on the floe-edge. But when I was growing up, the elders used to tell us not to do the narwhal hunting at the floe-edge," – Kik Shappa, Arctic Bay

The behaviour of hunters in Arctic Bay exposes them to the risk of getting stranded on drifting ice when it detaches from the landfast ice (ice that is attached to the land). There have been numerous incidents of hunters being stranded and having to wait on the drifting ice until rescued or until ice re-attaches to the landfast ice. Using experience and knowledge to identify precursors to hazardous conditions, hunters manage the risks of narwhal hunting; a south wind, for example, is avoided. With the

increasing unpredictability of the wind, however, accurate recognition of precursors is increasingly problematic.

Inuit risk assessment when making decisions regarding hunting has also changed in other ways, with people more likely to harvest in spite of poor weather conditions today. This is partly due to the reduced time available to harvest. Many hunters have full or part-time jobs in addition to hunting activities. Time off from work, which is used for hunting trips, has to be booked weeks, if not months, in advance. Weather or safety concerns may, therefore, be superseded by consideration of time availability when harvesting decisions are made. When a trip has been planned and time taken off, hunters are strongly motivated to proceed with hunting, even in the case of poor weather or unsafe hunting conditions. More risk-taking behaviour is also associated with technological developments. Global Positioning Systems (GPS), two way radios, and the functioning of a community search and rescue group, which provide a safety net if problems are encountered, have resulted in less caution and overconfidence. Consequently, hunters are now travelling and hunting in conditions that would have traditionally been considered dangerous.

The exposure-sensitivities of Arctic Bay residents are dynamic and reflect the interaction of climate and other environmental conditions, with social, economic, political, and technological changes which affect Inuit livelihoods.

6.2. Adaptation to changing exposure-sensitivity

Changes in exposure-sensitivity are being managed in numerous ways. Hunters are making additional preparations before going out in response to the increasing risk of getting stranded. Many are taking extra food, gas, and supplies, as well as identifying safe areas where they can get shelter during summer boating.

> "Since the weather is unpredictable now you have take extra everything – extra grub and extra gas," – David Kalluk, Arctic Bay

Other responses seek to reduce the likelihood that dangerous conditions will be encountered while out on the land. People are becoming more risk averse, avoiding travelling on the land or water if they have reason to believe the weather is going to be bad, avoiding dangerous areas, avoiding travelling at dangerous times of the year, returning quickly if out on the land when weather conditions turn, and generally being more vigilant when engaged in day to day activities. Some have stopped taking part in the floe edge narwhal hunt altogether; an option not taken lightly given the social and cultural importance of narwhal hunting to Inuit in Arctic Bay. Technological adjustments are being undertaken. These include: the use of GPS when hunting at the floe edge to detect if the ice is moving; the more widespread use of vhf radio even on short trips to allow the community to be contacted in emergency situations, and; the consultation of satellite images of the sea ice provided in the local town offices prior to travel on the ice in spring, which identify areas of high risk of ice break-up. Equipment used in harvesting has also been modified. More powerful outboard boat engines to allow for shorter time spent on exposed water are being used and hunters are taking along small row boats to safeguard against the risks of getting stranded on drifting ice.

> "When I am going down to the floe edge I carry a boat," – Anonymous, Arctic Bay

Losses associated with lost or damaged equipment are shared within the household unit. Safety equipment is also shared between friends and family. In response to changes in accessibility of hunting areas, the timing and location of hunting has changed. For example, with the sea ice freezing-up later in the year, the ice fishing season is being delayed and the open water fishing season extended.

These strategies are largely behavioural and have been undertaken by individuals in response to changes that are being experienced, and in anticipation of future change. Responsibility for these strategies largely rests with the more experienced hunters who encounter, adapt to, and respond to changing climatic conditions through frequent trial and error experience out on the land. This knowledge is transferred through informal channels; young or inexperienced hunters often travel with or seek advice from these 'local experts' before hunting, and the knowledge will be communicated in person. Expert knowledge is also communicated informally through radio communications and will be discussed between friends and family.

Not all have equal access to these adaptation strategies. Technological adaptations, for instance, are only available to those who can afford them. For those who cannot afford the equipment, or do not have family to borrow from, lack of equipment can mean loss of livelihood or engagement in dangerous hunting activities. The effectiveness of adaptation also varies. The use of more powerful boat engines allows sheltered areas to be reached if the weather suddenly changes while on exposed water. The same technology also seems to increase exposure-sensitivity by increasing dangerous boating activities (high speed travel), and leads to activities in more dangerous conditions.

6.3. Determinants of adaptive capacity in Arctic Bay

Adaptations are manifestations of a systems adaptive capacity**.** The ability of the community of Arctic Bay to cope or deal with changing climate-related exposure-sensitivities is indicative of the community's adaptability. The adaptive capacity of the community is facilitated by traditional knowledge or *Inuit Quajimajatuqangit*, strong social networks, flexibility in seasonal hunting cycles, and institutional support. However, as will be documented in section 6.4, certain aspects of adaptive capacity have been undermined and have resulted in emerging vulnerabilities in certain sections of the community.

6.3.1. Traditional skills and knowledge (Inuit Quajimajatuqangit)

Environmental circumstances inevitably vary between hunting trips, which are characterized by unpredictability and change (Wenzel, 1991). *Inuit Quajimajatuqangit (IQ)*, traditional Inuit knowledge and a code of behaviour based on time-honoured values and practices, has evolved in this context to manage environmental conditions, including variability and unpredictability. While the nature of *IQ* has altered with changing livelihoods, it remains important today in Arctic Bay, and contributes to adaptability. Competence on the land and in the skills and technology necessary for safe and successful hunting are a highly valued aspect of *IQ*.

These aspects are developed and transmitted through experiences on the land, and from listening to and learning from elders and experienced individuals. This collective social memory is drawn upon to deal with routine events and respond creatively to novel events (McIntosh, 2000; Davidson-Hunt and Berkes, 2003). Hunters manage risks by: knowing the dangers of hunting; by taking precautions; knowing precursors to certain hazardous conditions; knowing how to survive if they are caught in bad weather; knowing what equipment to take along and what preparations to make; and, especially for the more experienced hunters, knowing how to navigate using traditional means if they are caught out in bad weather (Nelson, 1969, 1982; Aporta, 2002, 2004; George et al., 2004; MacDonald, 2004). The knowledge embodied in *IQ* goes beyond what is essential for success. This is reflected, for example, in the equipment hunters take on trips. Hunters learn from a young age to take along survival equipment even on short trips and to prepare above what is necessary. When faced with an emergency situation, extra preparation enhances chances of survival; if stranded by bad weather, the extra food, naphtha, and warm clothes that hunters take along increases safety.

Like other forms of indigenous knowledge, *IQ* is dynamic, continually evolving and being updated and revised in light of observations, trial and error experience, and the incorporation of non-traditional knowledge alongside the traditional (Stevenson, 1997; Berkes, 1999; Usher, 2000; Davidson-Hunt and Berkes, 2003). Emerging out of experience with increased exposure and successful adaptations, and collective discussion of them, *IQ* has evolved and changed in response. Increasing unpredictability of climatic and environmental conditions are now part of the collective social memory that frames individual practice and decision making in Arctic Bay.

> "I think the hunters now are more aware of it [changing climatic conditions] so they are preparing," - Tagoonak Qavavauq, Arctic Bay

Moreover, as a repository of accumulated experience and knowledge of changing conditions and experience of successful adaptations, *IQ* allows 'response with experience' to changing exposure. This increases adaptive capacity (Berkes et al., 2003; Tengo and Hammer, 2003). It is this dynamic nature of *IQ*, its ability to learn and adapt to change, which confers adaptability. However, as will be discussed in section 7, there are limits to adaptability conferred by Inuit knowledge, and inequality in the extent to which it is has been transferred.

6.3.2. Social networks

Social networks refer to the relations of trust and reciprocity that enable people to act collectively (Pelling, 1999; Woolcock and Narayan, 2000; Adger, 2003b). They are a key component of adaptive capacity, enhancing security and reducing risk (Adger, 2003b; Robards and Alessa, 2004; Tompkins and Adger, 2004). In the context of unpredictable and pervasive environmental change, complex networks of sharing, reciprocity, collective action, and exchange, characterized traditional Inuit communities (Boas, 1888; Stefanson, 1913; Damas, 1963; Balikci, 1968, 1970). These networks evolved from the challenges of living in the extreme Arctic environment (Balikci, 1970; Callaway, 1995). Sabo (1991), for instance, studying how Inuit on south Baffin Island managed environmental changes during the Little Ice

Age, found that food sharing, among other factors, contributed to adaptability in the face of external stress.

While the complex social networks described above are not now readily evident in Arctic communities, the "economy of sharing," as Wenzel (1991) describes it, remains central to Inuit livelihoods (Condon et al., 1998; Chabot, 2003; Usher et al., 2003). In Arctic Bay, there is a high level of interdependence between and within households; there is a sense of collective community responsibility and mutual aid; and sharing remains an affirmation of Inuit cultural identity.

> "That's the only way we survive, by supporting one another," – Lisha Qavavauq, Arctic Bay

These networks facilitate the sharing of food, equipment, knowledge, and ensure rapid response to crisis. The sharing of country food is considered obligatory, occurring between family, friends, and at certain times of the year to anyone in the community. When hunting is poor the success of one person, therefore, will benefit all others who are part of the sharing network. Moreover, with changing climatic conditions making certain areas inaccessible to people who don't have the equipment, knowledge, or time, shared food underpins their country-food security. The sharing of equipment such as GPS, radios, and other safety equipment is widespread and allows for safer travel on the land. Equipment is shared within the household unit and with friends. In coping with changing climatic conditions this is particularly important as limited employment opportunities in Arctic Bay combined with the expense of equipment would otherwise make such purchases prohibitive. The sharing of knowledge facilitates the communication of information about risks and adaptive strategies. Those knowledgeable and experienced on the land act as an 'institutional memory,' maintaining and transmitting local knowledge and providing information during periods of change (Berkes and Folke, 1998). Providing such guidance and information is considered an affirmation of Inuit identity, and the responsibility is taken seriously (Takano, 2004). A strong sense of community and mutual aid facilitates effective community response in times of crisis. If someone is lost on the land, or is having difficulties, the community mobilizes to send out a rescue team.

6.3.3. Resource use diversity and flexibility

Diversity and flexibility in resource use are widely recognized strategies for managing risk (Adger, 2000; Barnett, 2001; Colding et al., 2003). The propensity of Arctic environments to undergo fluctuations has created incentives for individuals to master a diversity of hunting skills and procurement activities (Krupnik, 1993; Berkes and Jolly, 2002). Balikci (1968; 1970), for example, demonstrates how, during periods of ecological pressure, the Netsilik Eskimos (traditional name for an isolated group of Inuit hunters), would historically utilize alternative hunting strategies. Sabo (1991) has shown how Inuit on south Baffin Island coped with environmental stresses of the Little Ice Age by rescheduling their hunting techniques and utilizing a sequence of procurement activities. In Arctic Bay today, harvesting is opportunistic: hunters will harvest what is available when it is available and where it is available, making *ad hoc* changes to take advantage of game availability and specific local conditions during hunting. Climate change creates new situations which are taken advantage of through the inventiveness and opportunism that are characteristic of the human ecology of

hunting. If the caribou hunt in August and September fails, for example, other species, such as walrus or seal, will be harvested. Substitution not only allows people to cope with variations in animal numbers but also enables them to manage variations in environmental conditions. If the freeze-up is late then hunters will extend fishing season and wait until it freezes to resume normal on-ice activity; if certain areas are not accessible due to limited snow cover for snowmobile travel then people will go to different locations. In addition, the diversification of food production away from a total reliance on country food has reduced vulnerability to changes in resource availability and accessibility.

6.3.4. Institutional support

For indigenous communities in the Arctic, the high costs of subsistence capitalization and operating costs require substantial cash investments (Reeves, 1993; Condon et al., 1995; Chabot, 2003). In light of changing exposure, investment in GPS, vhf radios, and more powerful boat engines are required for safety purposes. Such investments require significant capital outlay, and individuals who lose equipment in hunting accidents have to replace lost machinery to continue harvesting. This places a burden upon Northern indigenous communities which have limited employment opportunities and high rates of unemployment (Nuttall, 2000). Unemployment in Arctic Bay in 2001 was officially 22% (StatsCanada, 2002) and unofficially probably much higher. Well developed institutional support in the form of federal government monetary transfers, and emerging institutional support from the Nunavut Government and Lands Claim Institutions, plays an important role in providing financing to cover purchase of equipment necessary to cope with the changing exposure (The Lands Claim Institutions were set up to oversee the Nunavut Lands Claim Agreement which provided specific land, resource, and mineral rights and ownership to Inuit, along with $1.1bn in cash compensation). The Nunavut Harvester Support Program, for instance, provides annual lump-sum payments to a limited number of hunters to help cover costs of equipment and supplies. While this enhances the adaptive capacity of the recipients it can make hunting even less of an option for others, thereby increasing their vulnerability.

6.4. Emerging vulnerabilities

Limitations to adaptation are already evident. Flexibility in group size and group structure, for example, were utilized throughout history by Inuit as part of their resource utilization strategies to cope with climate variability and unpredictability (Balikci, 1968; Sabo, 1991; McGhee, 1996). These strategies are no longer available due to settlement in permanent communities (Berkes and Jolly, 2002). The increasing cost of technological adaptation measures also limits adaptation to change. Purchase of safety equipment to cope with changing climate conditions is expensive, and although institutional support plays an important role, it is nonetheless insufficient to cover all the additional costs. In other areas, those characteristics of Inuit society that traditionally facilitated adaptability have been altered as a result of radical changes in lifestyle over the last forty years. For certain sections of the community in Arctic Bay, particularly younger generation Inuit, the erosion of adaptive capacity has been pronounced.

The traditional mode of knowledge transfer and learning by which Inuit develop the skills to hunt safely and successfully no longer functions effectively. Much has been written about this since the 1960s (Nelson, 1969; Condon et al., 1995; Newton, 1995; Ohmagri and Berkes, 1997; Condon et al., 1998; Aporta, 2004; Takano, 2004). While initial predictions of the "Death of Hunting" (Nelson, 1969, p.383) may have been premature, and indeed wrong (Wenzel, 2001), the skills and knowledge possessed by younger generation Inuit have, nonetheless, eroded. Two main reasons for this in Arctic Bay are discussed here.

While subsistence activities remain important to younger generation Inuit, in Arctic Bay fewer are displaying the same degree of commitment or interest in harvesting.

> "[The younger generations] are not out there hunting," - Tommy Tatatuopik, Arctic Bay

The decline in participation and interest in hunting has been attributed to numerous factors: boys in their adolescence are no longer becoming physically involved in harvesting because of southern educational and cultural requirements; there is increased dependence on waged employment; language differences now exist between generations; there is an increasing lack of funds to purchase equipment; and hunting now competes with alternative activities such as computer games and TV, and the desire among youth to follow 'western' social norms (Condon et al., 1995; Ohmagri and Berkes, 1997; Kral, 2003; Takano, 2004). This disconnection from the land has had wide ranging implications. The processes by which *IQ* is developed and learned, requires experience being regularly out on the land and observing others. Few young generation Inuit are learning this way. While many go out on the land during late spring and the summer months or when they get the chance, this is insufficient for effective transmission and learning.

The disconnection of youngsters from the land is reinforced by the emergence of inter-generational segregation between young and older generations (O'Neil, 1986; Kral, 2003). Older generations have an important role; they act as an 'institutional memory,' maintaining and transmitting *IQ*, and taking younger generations on the land. Interviewees in their 40s and 50s recollected how they were taken out hunting regularly when they were young whether they wanted to or not: their fathers made them. This role is increasingly absent from the young people's world. Young interviewees complained of never being asked or told to go hunting. The decrease in involvement of older generations has numerous explanations: English has replaced Inuktitut as the dominant language among younger generations, older generations think that young Inuit are not interested in learning the traditional ways, and the Euro-American social norms of youth are far removed from the traditional upbringing of older generations (Kral, 2003).

The breakdown of the traditional mode of knowledge transfer indicates a loss of adaptive capacity among younger generations. Certain skills necessary for safe and successful harvesting have been lost, including traditional forms of navigation and the ability to maker snow shelters. Skills and information on what to do in certain dangerous situations, how to dress appropriately, what to take along on trips, and the ability to identify precursors to hazardous conditions are not being adequately transferred between generations.

> "It is more dangerous for [the younger generation] because they don't know the conditions, what to avoid," - Kautaq Joseph, Arctic Bay

> "We have lost the skills so much. What would have not been dangerous 50 years ago is now dangerous," - Leah Kalluk, Arctic Bay

This is buffered to a certain extent by inexperienced hunters often opting to hunt or travel with more experienced people. When younger generations go out on the land in absence of more experienced hunters, however, they are at increased risk.

The adoption of new technology and equipment buffers the erosion of traditional skills; the use of GPS means knowledge of traditional forms of navigation is no longer required, vhf radios allow the community to be contacted in case of an emergency, snow machines allow easy access to hunting grounds, and tents negate the need to know how to make an igloo. Technology, however, is in many ways a double-edged sword. While helping to buffer risk, it creates new risks, exacerbates others, and generates new vulnerabilities. Technology can create dependency. Difficulties may result, for example, if a GPS fails and people don't know how to navigate the traditional way. Concerns were also expressed that modern 'gadgetry' is replacing detailed knowledge of the land. Moreover, the dependence on such equipment for harvesting has increased the importance of monetary resources. This ties the community to the volatility of external markets and government transfers which are responsible for the majority of Arctic Bay's income. The recent closure of the Nanisivik mine, which in the years before its closure brought in $1.2 million in wages a year to Arctic Bay (DSD, 2002), highlights the economic vulnerability of northern communities. In the absence of other employment opportunities, the loss of income has forced many former employees to sell their hunting equipment which they can no longer afford. Particularly for young Inuit, the lack of monetary resources limits the opportunities to take part in harvesting activities, thus further re-enforcing the decline in participation and erosion of traditional skills.

The functioning of social networks is influenced by, among other factors, the distribution of endowments and relationships between community members (Pelling, 1999; Adger, 2003b; Tompkins and Adger, 2004). The decrease in importance of the extended family, the emergence of inter-generational segregation, decline in practice of traditional cultural values, concentration of resources in fewer hands, and the emergence of social tension, were noted in interviews and have weakened the relations of trust, reciprocity and exchange that have facilitated sharing and the pooling of risk.

> "We don't share as much as before," - David Kalluk, Arctic Bay

This weakening of the 'moral economy' can be viewed in the context of changing Inuit livelihoods. The development of a waged economy has, over time, resulted in rising inequality, individualized behaviour, and withdrawal from the traditional subsistence economy. Some community members who have jobs are no longer willing to share their income with family members who are unemployed, or who are engaged full time in the subsistence economy. The importance of money, along with externally imposed harvesting quotas, has created division and social tension. On the one hand

people want to exploit resources through developing commercial harvesting, while others see such development as counter to Inuit ways. Institutional support, to an extent, has emerged to fill the gap. In some ways this has increased adaptive capacity - people no longer starve in years where there are no animals, an occasional occurrence in the past. External institutional support, however, cannot provide an equivalent substitute for the erosion of internal, culture-based support provided by traditional sharing networks.

7. Vulnerability to future climate change

Future climate change is predicted to have implications for the nature of climate-related risks. Those changes which have increased the magnitude and frequency of hazardous conditions facing hunters are predicted to continue and increase the dangers associated with hunting and further affect access to hunting areas (see Table 2). Unprecedented changes will also occur. It is predicted that animals important in subsistence activities will undergo considerable change in both numbers and spatial distribution (Humphries et al., 2004). Seals, important in Inuit diet, are predicted to decrease in numbers (Stirling and Smith, 2004). Derocher et al. (2004) predict a decrease in polar bears, and Laidre and Hiede-Jorgensen (2005) indicate that narwhal may be vulnerable to changes in sea ice. In addition, climate change is expected to have implications for infrastructure. An increase in precipitation and precipitation intensity (Kattsov and Kallen, 2005) may cause problems for housing and infrastructure associated with run-off from the steep hillsides surrounding Arctic Bay, and permafrost thaw (Walsh, 2005) may result in infrastructure subsidence.

Analysis of current adaptive capacity indicates that the ability to deal or cope with these changes will vary among different groups in the community. Experienced hunters have a high level of adaptive capacity. They draw upon traditional Inuit knowledge to manage routine events and respond creatively to novel events, utilize a diverse array of hunting strategies to ensure successful hunting, and have a strong sense of collective responsibility. This will continue to facilitate safe and successful hunting in light of more hazardous conditions and reduced access. Potential limits to adaptability stem from a lack of monetary resources to purchase equipment necessary for safe hunting in light of changing conditions. For those who cannot afford such equipment, they may loose their livelihoods or have to engage in dangerous hunting practices. Adaptive capacity among young generations is limited. Current experience shows that when faced with dangerous and novel situations, young Inuit are often ill-prepared and don't know what to do. There is also evidence that youth are involved in more risk taking behavior and engage in more dangerous hunting practices. Climate change will increase the consequences of a lack of knowledge and more risk taking behaviour. The adaptability of younger generations to future climate change will depend upon the strength of *IQ*. Re-assertion of cultural values may counter the erosion of traditional knowledge. In the Inuit community of Igloolik, for instance, 'Land Camps,' whereby elders take young Inuit on the land for weeks at a time throughout the year and teach hunting skills, have been successful in developing essential survival skills and strengthening inter-generational relationships (Wachowich, 2001; Takano, 2004). Such formal initiatives are absent in Arctic Bay at present, although elders report taking more pro-active steps to promote *IQ* in the community in 2004.

The nature of predicted climate change is also important. Inuit livelihoods, culture, and food-security would be vulnerable to extinctions or significant changes in the distribution of certain animals. If there was complete loss of summer sea-ice cover, for instance, as predicted in some scenarios, polar bears would be unlikely to survive as a species and seals would be seriously affected (Hassol, 2004). Further, if climate change is rapid and unpredictable it is more likely to limit adaptability.

> "If [climate change is] all of a sudden I would have some concern, otherwise I am not too concerned," – Kik Shappa, Arctic Bay

8. Conclusion

Although climate change presents important vulnerabilities for numerous aspects of community life (infrastructure, human health), the vulnerabilities highlighted through this research are largely associated with traditional harvesting activities. A combination of changing climatic conditions and changing livelihoods has affected climate-related exposure-sensitivities in Arctic Bay. In several ways harvesting is now more dangerous and access to hunting areas is increasingly difficult. In particular, unstable ice conditions and weather unpredictability during the late spring narwhal hunt, and strong winds during the summer open water season, have been problematic. Inuit have demonstrated adaptability in light of these changes. This adaptability is facilitated by traditional Inuit knowledge and land based skills, strong social networks, flexibility in harvesting behaviour, and institutional support. The social, cultural and economic implications associated with changing Inuit livelihoods, however, have undermined the adaptive capacity of certain sections of the community. The changes in adaptive capacity are influencing the younger generations in particular. The experience of, and response to, future climate change will be facilitated and constrained by the same factors that have influenced past and present exposure and adaptive capacity. Analysis of current vulnerability indicates that future vulnerability will differ between social groups, will be affected by social, cultural, and economic conditions and processes, and according to the nature of climate change.

A number of insights about vulnerability analysis emerge from this research. It demonstrates that involving local stakeholders in vulnerability analysis is crucial. Analysis which starts with the community itself permits the identification and characterization of the complex social relations that create exposure and constrain and facilitate adaptive capacity. It highlights that vulnerability and its causes are location-specific. Exposure in Arctic Bay is associated with travel on the sea ice, especially the late spring narwhal hunt, and on open water in summer. Exposures differ significantly in other communities depending on the human ecology of harvesting. The determinants of adaptive capacity also vary widely. In Arctic Bay, the break-down of knowledge transfer and learning among younger generations has been particularly pronounced. Finally, it shows that local level vulnerability is dependent on the characteristics of the community also the broader environment within which the community functions. Social, cultural, political, and economic conditions and processes operating at various spatial-temporal scales influence how people experience, respond to, and cope with changing physical environments. In Arctic Bay, emerging vulnerabilities are associated with changing Inuit livelihoods which have exposed hunters to new risks and compounded the problems caused by changing climatic conditions, and undermined some attributes of Inuit society which facilitated

adaptive capacity. Livelihood change must be viewed in the context of external social-economic developments, government policy, the development of formal economic sector activities, and participation in and dependence on external markets.

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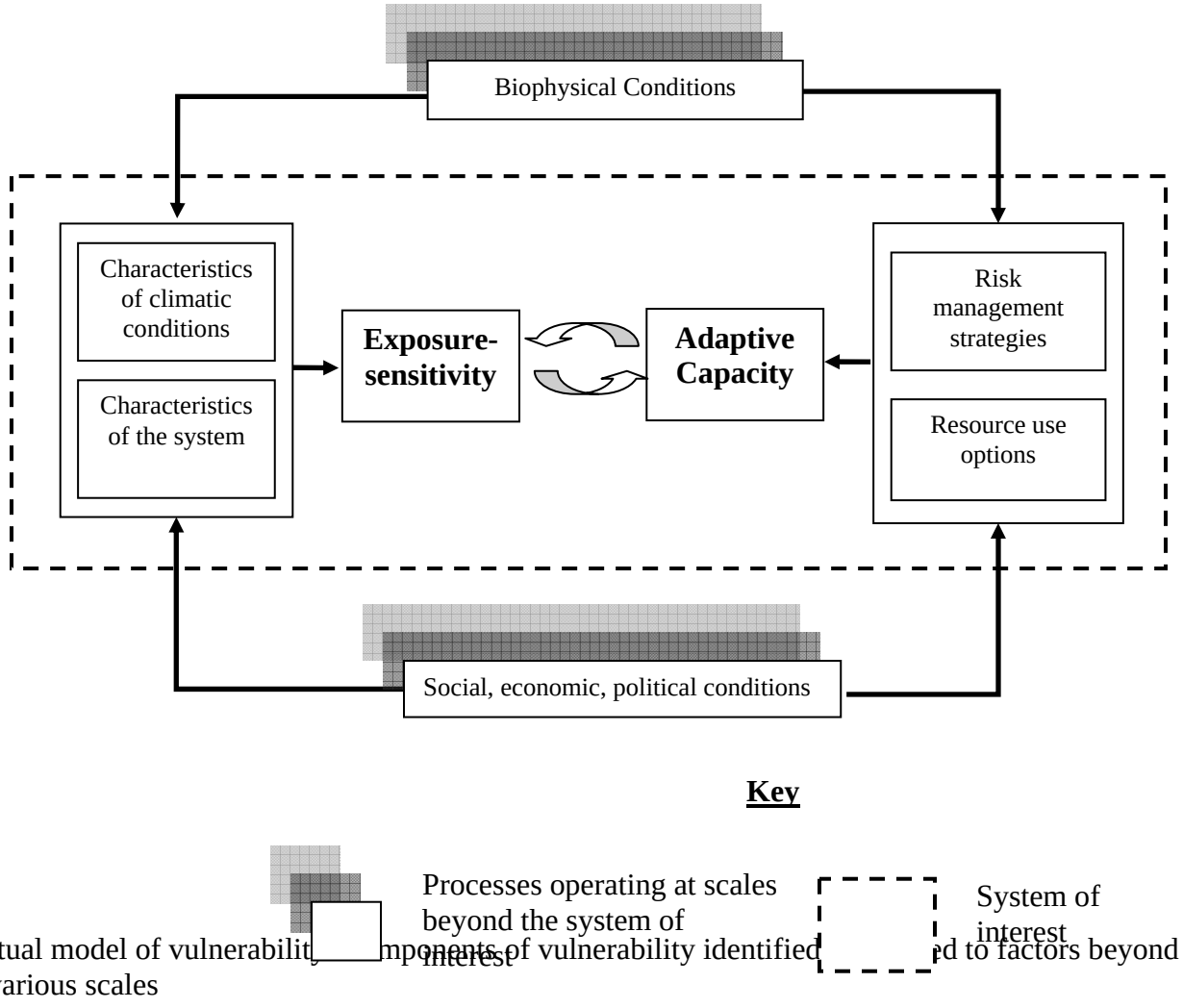

Fig. 1 - A conceptual model of vulnerability components of vulnerability identified ed to factors beyond the system of study and operating at various scales

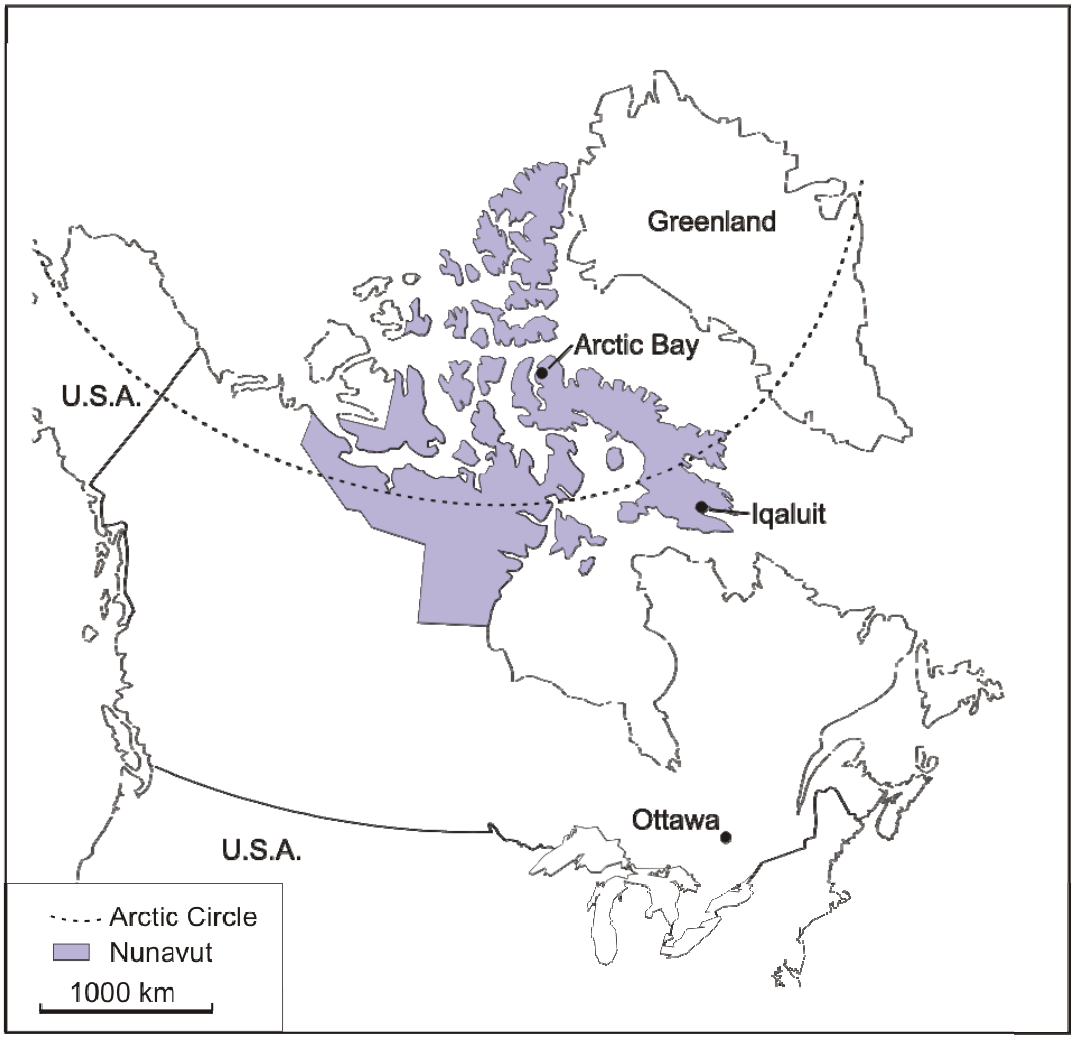

Fig. 2 – The Canadian Territory of Nunavut with Arctic Bay highlighted (map by Luke Powell)

Activity	Time of Year	Hazardous conditions	Implication of changing climatic conditions for hazardous conditions
General Hunting/ Travel on the sea ice	October-December	Thin Ice	New areas of open water, areas of unusually thin ice, and a change in the location of leads[a] have increased the dangers of travelling on sea ice and lake ice. People have lost and damaged equipment
	October-July	Weather	More unpredictable weather and sudden weather changes have forced hunters to spend extra unplanned nights on the land. Unusual weather – rain in winter, extreme cold in spring – is dangerous because hunters are not prepared.
Narwhal hunt	June-July	Ice break-up	Sudden and unanticipated wind changes causing sea ice to unexpectedly disintegrate. Incidences of hunters being stranded on drifting ice[b] and having to be rescued by helicopter
General Hunting/ Travel by boat	July-September	Waves/Stormy weather	Sudden changes in wind strength and direction, combined with stronger winds, have forced hunters to spend extra nights out on the land waiting for calm weather to return to the community.

[a] A crevice or channel of open water created by a break in a mass of sea ice
[b] Drift occurs if the ice is blown away from ice that is attached to the land

Table 1 – Implications of changing climatic conditions for hazards associated with harvesting in Arctic Bay

Current hazardous conditions	Climate change predictions	Implications
Thin ice	Decrease in sea-ice extent and thickness (Johannessen et al., 2004; Walsh, 2005)	• Travel on ice more dangerous especially in fall and late spring • Reduced access to hunting areas
Ice break-up	Reduced stability of sea ice (Walsh, 2005)	• Travel on ice more dangerous • Floe-edge narwhal harvest more dangerous
Weather	Increases in mean precipitation, precipitation intensity, and spring precipitation (Kattsov and Kallen, 2005)	• Dangerous if hunters are not prepared for wet conditions.
Waves/stormy weather	Potential increase in weather extremes, storminess (Houghton et al., 2001)	• Increased danger of summer boating • Decreased access to summer hunting grounds

Table 2 – The implications of future climate change for community identified hazardous condition