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Inuit vulnerability and adaptive capacity to climate change in Ulukhaktok, Northwest Territories, Canada

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ABSTRACT. Climate change is already being experienced in the Arctic with implications for ecosystems and the communities that depend on them. This paper argues that an assessment of community vulnerability to climate change requires knowledge of past experience with climate conditions, responses to climatic variations, future climate change projections, and non-climate factors that influence people's susceptibility and adaptive capacity. The paper documents and describes exposure sensitivities to climate change experienced in the community of Ulukhaktok, Northwest Territories and the adaptive strategies employed. It is based on collaborative research involving semi-structured interviews, secondary sources of information, and participant observations. In the context of subsistence hunting, changes in temperature, seasonal patterns (for example timing and nature of the spring melt), sea ice and wind dynamics, and weather variability have affected the health and availability of some species of wildlife important for subsistence and have exacerbated risks associated with hunting and travel. Inuit in Ulukhaktok are coping with these changes by taking extra precautions when travelling, shifting modes of transportation, travel routes and hunting areas to deal with changing trail conditions, switching species harvested, and supplementing their diet with store bought foods. Limited access to capital resources, changing levels of traditional knowledge and land skills, and substance abuse were identified as key constraints to adaptation. The research demonstrates the need to consider the perspectives and experiences of local people for climate change research to have practical relevance to Arctic communities such as for the development and promotion of adaptive strategies.

Contents

Introduction

There have been rapid social, economic, and political changes in the Canadian Arctic during the last half of the twentieth century (Irwin 1989; Hamilton 1994; Damas 2002). These changes have transformed Inuit harvesting practices, community social networks, and cultural and spiritual traditions (Wenzel 1991; Kral 2003; Einarsson and others 2004). Furthermore, Inuit are increasingly exposed to risks associated with climate change (Krupnik and Jolly 2002; Huntington and Fox 2005). Local observations and instrumental measurements have indicated changes in temperature and precipitation, permafrost, coastal erosion, and ice instability (McBean 2005; Gearheard and others 2006; Nickels and others 2006; Zhang and others 2006; Manson and Solomon 2007; Stroeve and others 2007; Laidler and Ikummaq 2008). These changes are already affecting Arctic communities, and scientists project that they will continue in the future with further implications for the Arctic environment and people (Kattsov and Kallen 2005; Anisimov and others 2007).

Research on climate change in the Arctic has provided considerable information about the implications of climate change for physical and biological systems (for example Callaghan 2005; Loeng 2005). There has been less work regarding the implications of climate change for people and their livelihoods, and their capacity to deal

with and adapt to changing conditions. It is increasingly recognised that to understand better what climate change means for people and communities requires knowledge of how people experience and respond to changing conditions that are relevant to them, including the role of non-climatic drivers (for example demographic, economic, sociopolitical, motivational, technological, etc.) (Duerden 2004; Ford and Smit 2004; McCarthy and Martello 2005; Ford and others 2008b). This paper uses a vulnerability framework described by Ford and Smit (2004) and the IPCC (2007) to identify the conditions to which community members in Ulukhaktok, Northwest Territories (NWT) are sensitive. The study highlights climate related changes to which the community is exposed and the associated adaptive capacities. This provides a baseline on which to assess vulnerabilities and generate insights on the adaptability of people in Ulukhaktok to continuing climate change.

The paper first provides a review of climate change and impacts in the Arctic, noting the evolution of analytical approaches, and describes the main features of the vulnerability framework on which the Ulukhaktok case study is based. The community of Ulukhaktok is briefly described, and the empirical methodology employed is outlined. The results are presented first for current vulnerability (that is current exposure-sensitivities and adaptive strategies), and then for future vulnerability (that is future exposure-sensitivities and adaptive capacity).

Climate change, vulnerability and adaptation in the Arctic

There is strong consensus in the international scientific community that the global climate is changing, and these changes are already being experienced in the Arctic (ACIA 2005; Anisimov and others 2007; Furgal and Prowse 2008). The main response to concerns over climate change has been to seek reductions in greenhouse gas emissions to 'mitigate' changes to the climate system (UNFCCC 2002), and the importance of mitigation has been argued by Inuit representatives (Ford and others 2007; Martello 2008). However, it is recognised that even under the most aggressive control measures, greenhouse gas emissions commit the Earth to some degree of climate change, with effects requiring communities to undertake adaptations (Klein and others 2005; Hare and Meinshausen 2006; IPCC 2007). Adaptation is particularly important in the Arctic where climate change is already affecting the local environment and northern livelihoods.

Several approaches have been employed to assess the implications of climate change in the Arctic and the prospects for adaptation. Impact studies, based on projected future emission trends, have developed climate change scenarios to model the potential biophysical impacts of future climate change (McCarthy and others 2001; ACIA 2005). These studies are conducted at broad scales, and focus on long term changes in average climate conditions (for example annual mean temperature, precipitation, and sea level rise, variables most readily available from climate models) for the purpose of quantifying the net impact of climate change, mostly in ecological terms. The role of the human system is typically downplayed, with vulnerability being viewed in terms of estimated changes in physical and biological variables that may be relevant to human occupancy and livelihoods. Arctic climate impact studies have improved our understanding of the potential severity of the broad affects of climate change on ecosystems, but they do not explicitly address adaptation.

A growing body of studies is providing insights into how climate change is being experienced in the Arctic, by northerners, beyond the variables included in climate change models, and how Arctic people are being affected (for example Berkes and Jolly 2002; Wesche and Armitage 2006; Huntington and others 2007; Ford and others 2008b; Sakakibara 2008). Arctic residents have noted changes in sea ice dynamics and weather variability which have affected the health and availability of some species of wildlife important for subsistence and have exacerbated risks associated with hunting and travel (Riedlinger 2001; Furgal and Seguin 2006; Tremblay and others 2006; Ford and others 2008a). Community infrastructure has also been affected by coastal erosion and permafrost degradation (Couture and others 2001; Smith and Levasseur 2002; Instanes 2005). While this work has greatly enhanced understanding of the human dimensions of climate change, there has been limited research done on the interconnections between climate and non-climatic factors that influence vulnerability.

To initiate adaptation actions, decision makers need to know the nature of vulnerability, in terms of who and what are vulnerable, to what stresses, and in what way, and also what is the capacity of the system to adapt to changing conditions (Smit and others 2000; Turner and others 2003; Schroter and others 2005). In the climate change field, the term 'vulnerability' refers to the susceptibility of a system (community) to harm relative to a climate stimulus or stimuli, and relates both to sensitivity to climate exposures and capacity to adapt (Adger 2006; McLeman and Smit 2006; Smit and Wandel 2006). Beyond the climate change impact research, studies have built on the natural hazards field to focus on the social dimensions of human sensitivity and adaptability, and have considered vulnerability to climate change in the context of the other economic, social, cultural and environmental forces that affect communities (Adger and others 2001; Kasperson and Kasperson 2001b; Cutter and others 2003). Some vulnerability studies aim to calculate comparative rankings or indices (for example Downing and Patwardhan 2003; O'Brien and others 2004), others seek to identify and describe the nature of vulnerability, its underlying forces and its dynamics (for example Adger and Kelly 1999; Parkins and MacKendrick 2007; Tschakert 2007). Furthermore, it is now widely accepted that adaptation initiatives are most effective when they are integrated, or mainstreamed, into other resource management, disaster

preparedness, and/or community planning programmes and institutions (Burton and others 2002; Huq and others 2003; Ford and others 2007; Klein and others 2007). This integration requires knowledge of local institutions and policies as well as the forces that influence vulnerability and the factors that facilitate or constrain adaptation. A research perspective that addresses these needs, and has been recognised by the ACIA (2005), IPCC (2007) and Canada's national assessment on climate change report (Lemmen and others 2008) is the 'vulnerability approach.'

The vulnerability approach seeks to describe the processes and forces that influence and structure vulnerabilities in particular places to help identify why vulnerability exists and to identify opportunities for facilitating adaptation. The vulnerability approach includes two stages of assessment. The first stage assesses current vulnerability by documenting how people are exposed and sensitive to climatic variables, and the adaptive strategies employed to deal with these conditions. The second stage assesses future vulnerability by incorporating future climate change probabilities and future social probabilities to estimate directional changes in exposure-sensitivities and associated adaptive capacities (Ford and Smit 2004).

Exposure-sensitivity refers to the susceptibility of people and communities to variable conditions. It is a joint property of the community characteristics (location, livelihoods, economy, infrastructure, etc.) and the characteristics of climate related stimuli (magnitude, frequency, spatial dispersion, duration, speed of onset, etc.) (Cutter 1996; Adger, 2006; Smit and Wandel 2006).

Adaptive capacity and adaptation are closely related. Adaptive capacity refers to the potential of a community to adapt to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2007). Determinants of adaptive capacity include the availability and distribution of resources, available technology, structure and function of institutions, human capital including education and personal security, social capital including property rights, ability of decision makers to manage information, and the public's perceived attribution of the source of stress (Yohe and Tol 2002; IPCC 2001, 2007). These attributes will differ among regions, communities, and individuals and will vary over time, translating into different capacities to adapt (Adger and Kelly 1999; Duerden 2004). Adaptations are the manifestation or the realisation of adaptive capacity (Smit and others 2000; Brooks 2003). For example, Inuit hunters have extensive knowledge of the local environment and routinely respond to and adjust their behaviour to accommodate risks. Environmental knowledge and land skills are a source of adaptive capacity or adaptation potential. This potential is manifested as adaptation when the hunters draws on their knowledge and experience to navigate over unstable sea ice to continue to access hunting areas.

Variations of the vulnerability approach have been applied in several geographic regions and contexts (for example Adger 1999; Eriksen and others 2005; Sutherland and others 2005; Belliveau and others 2006; McLeman and Smit 2006; Pouliotte and others 2006; Wall and Marzall 2006), and in the Arctic (for example Pratley 2005; Duerden and Beasley 2006; Furgal and Seguin 2006; Ford and others 2006a; Ford and others 2006b; Huntington and others 2007; Tyler and others 2007; Wolfe and others 2007; Keskitalo 2008a, 2008b; Ford in press). In many cases, climatic and non-climatic factors have acted synergistically to affect individuals and communities, and studies of vulnerability are increasingly considering the multiple variables that drive exposure sensitivities and adaptations. These studies have also shown that how climate change is experienced will differ among regions, communities, and individuals as a result of different geographies, economies, traditions, access to resources, and institutional structures. Case studies provide an effective means of identifying local effects of climate change and adaptation processes (Jones 2001). The vulnerability research reported in this paper was undertaken for the case study of Ulukhaktok. Ulukhaktok is one of many Arctic communities that is experiencing climate change, and is having to adapt. To extend existing information on aggregate changes in physical conditions and local observations of climate change in the Arctic, research was conducted to examine the exposure sensitivities, and adaptations specific to the people of Ulukhaktok.

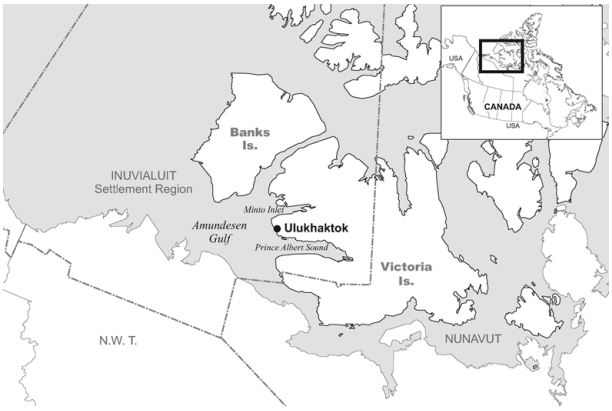

Fig. 1. Location of Ulukhaktok and selected hunting areas in the Inuvialuit settlement region, NWT, Canada.

Case study

Ulukhaktok

Ulukhaktok is a coastal Inuit community of approximately 430 people (96% Inuit) (NWT Statistics 2006) located on the west coast of Victoria Island (70°45′42′ N, 117°48′ 20′ W) in the Inuvialuit settlement region (ISR), NWT (Fig. 1). Victoria Island is the second largest island in the Canadian Arctic archipelago. The area around Ulukhaktok is characterised by lowlands, hills and rugged plateaux, and numerous ponds, lakes and rivers. The ISR was created in 1984 with the signing of the Inuvialuit final agreement (IFA), a land settlement agreement between six Inuit communities and the Canadian Government.

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Federal and territorial government agencies and Inuvialuit organisations jointly manage social, economic, political, and environmental issues in the ISR including education, health care, fish and wildlife management, and resource development (Fast and others 2001).

Ulukhaktok evolved as a permanent settlement starting in 1939 with the establishment of a Hudson's Bay Company (HBC) trading post and a Roman Catholic mission near the location of the current settlement. Throughout the 1940s and 1950s, the regional population continued to live in isolated hunting and trapping camps and came to Ulukhaktok several times a year to trade furs and socialise. Inuit in Ulukhaktok are largely descended from the northernmost groups of Copper Inuit: the Kangiryuarmiut of Prince Albert Sound and the Kangiryuatjagmiut of Minto Inlet (Condon and others 1995). In the 1930s and 1940s, several western Inuit (now called Inuvialuit) from the Mackenzie Delta region moved into the Ulukhaktok area for the purposes of trapping or employment at the HBC or the Roman Catholic mission (Condon and others 1995). As a result of the closing of the Reid Island HBC trading post on southern Victoria Island in the early 1960s, several Puvilingmiut families also moved to the Ulukhaktok area (Condon and others 1995). In 1967 the last family to remain on the land moved into the settlement and the settlement has since expanded considerably (Condon and others 1987).

The present community is described as a 'modern Inuit town' (Stern 2001). There is a school from kindergarten to grade twelve, a satellite campus of Aurora College, a health care centre, arena, community hall, hotel and restaurant, artist print shop, two grocery stores, and a convenience store. Like many communities in the Canadian Arctic, bulk supplies are transported to the settlement annually by barge and weekly year round flights from Yellowknife and Inuvik provide much needed medical and health services, and are vital transportation links for mail, perishable foods, passengers, and freight.

Since the mid-1980s the settlement, rather than the land, has increasingly become the focus of daily life for many residents, and wage income is an important component of Ulukhaktok's economy. 25% of Inuit adults in Ulukhaktok between the ages of 18 and 64 years have full time wage employment, another 25% have regular part time jobs, and the remainder are either dependent on another wage earner or derive their income from subsistence earnings, seasonal employment (for example guiding and helping sport hunts, wildlife monitoring, mineral exploration), casual work or social transfer payments (Condon 1987; Stern 2001).

Despite undergoing sweeping social, political and economic changes, subsistence hunting, fishing and trapping continue to be valued activities among Inuit in Ulukhaktok. 76% of community members participate in hunting and fishing and country foods (locally harvested fish and wildlife) are the primary source of meat for 46% of households (NWT Statistics 2006). Arctic char, *iqalukpik* (*Salvelinus alpinus*), ringed seal, *natiq* (*Phoca hispida*), bearded seal, *ugyuk* (*Eringnathus barbatus*), lake trout, *ihuuhuk* (*Salvelinus namaycush*), Peary caribou, *tuktu* (*Rangifier tarandus*), Dolphin-Union caribou, *tuktu* (*Rangifer tarandus groenlandicus x pearyi*), muskox, *umingmuk* (*Ovibos moschatus*), King Eider ducks, *kingalik* (*Somateria spectabilis*), and snow geese, *kanguq* (*Chen caerulescens*) are common species that are hunted for subsistence. Although to a much lesser extent than in the past, Arctic fox, *tirigannia* (*Vulpes lagopus*) and Arctic wolf, *amaruq* (*Canis lupus arctos*) are trapped for their pelts that are sold at southern auctions. Participation in harvesting varies among community members with some people continuing to hunt full time and others balancing hunting with wage employment. Condon and others (1995) and Collings and others (1998) documented several interconnected variables influencing individual participation in subsistence harvesting in Ulukhaktok including age, employment, family histories, motivation, skill and knowledge levels, access to capital equipment, and availability of time. Climate change is but one of several factors affecting involvement in harvesting activities and is considered as such in this analysis of vulnerability.

Methods

Research Approach

This research was undertaken with community members in Ulukhaktok using a vulnerability approach described in detail by Ford and Smit (2004) and Smit and Wandel (2006) and consistent with Kasperson and Kasperson (2001a), Turner and others (2003), Fussel (2007), and Keskitalo (2008a).

The four steps of the vulnerability approach are:

- Identify the conditions or risks (climate related and other) that are relevant to the people in the community (referred to as exposure sensitivities).
- Identify and assess the strategies employed in the community to cope with and adapt to exposure sensitivities.

Together these components are considered 'current vulnerability.' The next two components relate to 'future vulnerability:'

- Estimate future risks or exposure sensitivities based on likely changes in conditions that have been identified as important to community livelihoods.
- Assess the capacity of the community to adapt to future conditions based on current adaptive capacity and future demographic and socio-economic projections.

Information on each of the four components of the vulnerability approach was obtained primarily from data collected through semi-structured interviews with community members and also from secondary sources of information and participant observation. The documentation of northern people's experiences with climate change using semi-structured interviews builds on the work of

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Table 1. Characteristics of the interview sample in Ulukhaktok.

	Aboriginal		Non-aboriginal		
	Male	Female	Male	Female	Total
Age					
18–28	6	3	0	0	9
29–39	7	3	0	0	10
40–49	7	2	0	0	9
50–59	4	1	0	1	6
60–69	12	4	2	0	18
70–79	0	4	0	0	4
80+	3	3	0	0	6
Total	39	20	2	1	62

many scholars working in the Arctic including, Berkes and Jolly (2002), Krupnik and Jolly (2002), Fox (2004), George and others (2004), Ford and others (2006a), Ford and others (2006b), and Nickels and others (2006). The procedures for community selection, engagement, and participation followed the guidelines of Aurora research institute (2004), and ITK and NRI (2007). Communication was initiated with the Inuvialuit game council (IGC) and with representatives from each of the six Inuvialuit communities early in research planning. This resulted in an expression of interest from the representatives from Ulukhaktok in having the research conducted in their community, citing changes in the environment and community concerns for affects on wildlife and subsistence hunting. A consultation visit to Ulukhaktok was conducted over a two week period in April 2005, including meetings with the hunters and trappers committee (HTC), community corporation, and hamlet council. Community feedback was integrated into the research design, including the timing of fieldwork, data collection techniques, and language considerations. The support of each organisation was obtained, a NWT research licence was acquired, and three local collaborators, selected in consultation with community representatives, were hired (A. Goose (interpreter), R. Inuktalik and F. Kataoyak (research assistants)). The interpreter played vital roles in the field research, including translator (Inuinnaqtun and English), research assistant, community liaison, cultural guide and teacher. The research assistants facilitated interviews. They identified respondents, scheduled interviews and helped conduct interviews, collected economic and social data in the community, communicated the research objectives to community members, and collaborated with university researchers to present research finding in the community and elsewhere. The lead author worked with the local collaborators and others to interpret the data and develop results. Local collaborators and other community members provided comments on earlier drafts of this manuscript (in person and via the phone and E-mail), and several of these comments have been integrated into the text. Primary data collection was conducted in Ulukhaktok over a four month period between May and September 2005. The methods used to engage community members in the design, development, application, and dissemination of the research are described in detail in Pearce and others (in press).

Data Collection

Over a period of five months, 62 semi-structured interviews were conducted with a cross section of community members 18 years old and older to identify those climate related conditions and risks that people have experienced, and are currently experiencing; to gain insights on the strategies being used to cope with and adapt to these conditions; and to identify factors that influence their exposure sensitivity and adaptive capacity to projected future climate change. A purposive sampling strategy was used to recruit respondents from different age and gender cohorts and people who were involved in different sectors of the local economy. A snowball sampling method was then used in which community research partners identified people willing to participate in the research, who then led to others who were willing to be involved (Bernard 2000). A description of the research sample is provided in Table 1. The male bias (41/21) may be due to a combination of factors including, the tendency for families to have a male representative speak on their behalf, the male dominance in the research team (3/4), and a higher proportion of males in the hunter and elder cohorts.

Interview questions were open ended and the interviews were guided by a semi-structured interview guide. The open ended structure was adopted to minimise interview bias or prompting and to allow respondents to describe their experiences and actions from their perspectives and in terms that made sense to them and reflected their priorities (Ferguson and Messier 1997; Fienup-Riordan 1999). For example, people were asked to describe conditions they have had to deal with in their lives and livelihoods, rather than asking how climate change affects or might affect them. Semi-structured interviews are a standard method of data collection used in ethnography for gathering information in an open ended format and are widely used in northern research (Huntington 1998; Cruikshank, 2001; Riedlinger and Berkes 2001; Noongwook and others 2007). Interviews

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were undertaken with two community research partners, were conducted in Inuinnaqtun or English, and were most often conducted at the respondent's home. The interviews conducted in Inuinnaqtun were translated during the interview. Interviews were voluntary and interviewees had the option of remaining anonymous or having their information attributed to them. Respondents also had the option of having their interview audio recorded. 38 interviews were audio recorded and later transcribed and the other interviews were recorded in writing during the interview. After each interview, transcripts were reviewed and verified by the interview team. The interview quotations provided in the text are from both audio recordings and hand written transcripts. Three additional research trips were made to the community (4.5 months in the community) between 2005 and 2008 to verify interview data, collect additional information on identified themes, confirm that the data was being interpreted the way that respondents intended it to be, and to collect feedback on previous versions of this manuscript.

Interviews were complemented with informal meetings and experiential trips on the land with community members. These experiences helped contextualise information shared by interviewees about the local environment and harvesting activities. Secondary sources of information including government and community reports, economic and harvesting data, climate records, books, and journal articles were analysed and incorporated as appropriate in the assessment of vulnerabilities.

Data analysis

Using the principles of latent content analysis (Dunn 2000), the interview data were scanned to identify common or recurring themes or processes related to exposure sensitivities and adaptation. Interview data were coded and analysed based on these themes using NVivo (QSR International), qualitative data analysis software. Each coding scheme was cross-referenced to identify instances where multiple themes were discussed together. Given that the themes and processes identified in this exercise involve interpretation of raw data, and given that the original expressions provide particular insights, the presentation of findings includes direct quotes to illustrate how the information was originally supplied and how the broader context was seen by the respondent. Interview data are complemented, when available, with data from secondary sources of information including, instrumental records, community reports, and past research. Secondary sources of information are referenced throughout the text.

Current vulnerability

Exposure sensitivities

In the context of subsistence hunting, changes in temperature, seasonal patterns, sea ice and wind dynamics, and weather variability have affected the health and availability of some species of wildlife important for subsistence and have exacerbated risks associated with hunting and travel (Table 2). These climatic changes are expected to continue into the foreseeable future, with further impacts on Inuit in the social, cultural, and economic sectors of society (Anisimov and others 2007).

Increased Travel Risks

Travelling and harvesting on the land, water and sea ice is inherently dangerous and Inuit have long known about and coped with these risks. However, in recent years, changes in the climate have altered and in some cases increased the magnitude and frequency of hazards with which people have to deal. In particular, hunters are increasingly exposed to hazards associated with more variable and less predictable weather. The weather changes quickly with minimal warning, and it is difficult to forecast wind direction and the development of storms. These conditions have also been recorded in other northern locations (Krupnik and Jolly 2002; Simpson and others 2002; L'Heureux and others 2004).

There is an increased occurrence of strong winds that now last for weeks at a time and are described as 'constantly going' (Alikamik 2005). Less predictable weather, strong winds and severe storms make travel and harvesting difficult, if not impossible, and increasingly hazardous. 'White-out', *niptiaktuk*, conditions reduce visibility and travellers have been separated from their travel partners, lost, stranded, and have encountered hazards such as driving their snow machines over cliffs, a hazard that would be avoided in better visibility. In the past, people travelled by dog team and the dogs were able to navigate through reduced visibility, but today people are travelling faster by snow machine, often with limited supplies, and risk becoming lost and encountering hazards when visibility is poor. In the past, Inuit hunters relied on knowledge of the local environment to forecast and navigate weather events. Under changing climate conditions, however, harvesters explain that they are unable to read signs in the weather like they used to because the weather and seasonal changes no longer follow regular patterns.

> . . .it can be very cold one day and the next day it's the opposite, it's too mild. In January some days it's really cold for several days and then so many days just after being so very, very cold the weather gets really mild for several days. It's not a balanced winter anymore. – Anonymous (translated from Inuinnaqtun)

Harvesters reported that they are increasingly faced with changing sea ice conditions in the autumn, winter, and spring. Some areas of sea ice, over which harvesters are accustomed to travel, are no longer stable and in some instances the ice has not formed. Even experienced harvesters have encountered hazards in what are thought to be safe travel areas. Greater variability, less predictable weather, and changing sea ice conditions make it difficult to know when conditions are suitable for travel and there is uncertainty among hunters about the safety of travel. In recent years, several travellers have been stranded, injured, forced to take alternative travel routes, and/or have lost or damaged equipment (for example snow

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Table 2. Current climate related exposure sensitivities in Ulukhaktok.

Exposure sensitivities	Observed changes	Description
Increased travel risks	• More variable and less predictable weather • Increased storminess and strong winds • Changing sea ice dynamics • Rapid seasonal transitions	• Hazardous travelling conditions • Difficult to know when conditions are suitable for travel • Harvesters have become stranded, injured and/or have lost or damaged equipment
Compromised travel routes	• Spring melt happens earlier and is more rapid • Flooding rivers in the spring • Inland lakes become slushy earlier and melt faster • Longer autumn – without snow on the ground • Earlier sea ice break-up and later freeze-up • Incomplete freeze-up and unstable ice • Changing wind-ice regimes	• Snow machines become stuck in melting snow • High rivers block access to spring hunting and fishing areas • Travelling by ATV later into the autumn • Reduced access to hunting areas for ducks, polar bear, and caribou
Quality and availability of wildlife	• Fewer young ringed seals • Ringed seals are very lean and appear to suffer from malnutrition • Freeze-thaw events hinder travel of caribou and make it more difficult to forage for food – decline in population (Russell, 2007) • Changing wind-ice regimes affect travel by boat to caribou hunting areas	• Decline in young seals harvested – less country food • Meat and pelts are poor quality and hold little economic value • Moratorium on harvesting animals from the Minto Inlet population • Harvesters must travel long distances by boat to harvest caribou from the Dolphin Union population • Involvement in caribou harvesting is constrained by access to a boat, fuel, and time

machines breaking through the ice) due to unexpected changes in weather and sea ice conditions.

Compromised travel routes

Changes in the nature and timing of the spring melt, wind patterns, sea ice dynamics, and fluctuations in temperature have affected travel routes to hunting areas. The spring is a popular time for community members to travel on the land to ice fish at lakes and hunt musk-ox, and on the sea ice to hunt seals, ducks, and polar bears. However, in recent years the spring melt has happened earlier and more rapidly and this is making travel by snow machine more difficult and sometimes impossible. An elder and active hunter, recognised in the community for his knowledge of the weather and environment, explained that in the years that he has been travelling on the land the spring melt usually started in May and June and the snow would melt gradually from the top down. In the last five years the melting has started from underneath the surface of the snow, and although snow conditions appear to be good for travelling, they are not because there is so much moisture and water under the snow that snow machines can become easily stuck (Akoakhion 2005).

> Long ago you could be out on the land for several weeks, not afraid of [the] spring thaw happening. There is no notice now. [The] snow gets soft really fast and warm winds come up. Trails under the snow melt very fast. There is a greater chance of getting stuck and having to drag your machine out. It makes travel harder. George Okheena (translated from Inuinnaqtun)

Rapid periods of melting have also caused rivers to flood, and lakes are becoming 'slushy' earlier which has affected travel routes on the land and spring ice fishing.

These observations are consistent with instrumental records in the western Arctic: an increase in the number of days with thaw (defined as a day with snow on the ground when the daily mean temperature is above -2°C (Brown 2000) has been recorded over the past fifty years (Smith 1998; Groisman and others 2003).

Later and incomplete sea ice freeze-up and earlier, more rapid break-up are also affecting access to hunting areas. Recorded fluctuations in surface air temperatures during fall and winter months over the past two decades in the western Canadian Arctic have delayed and sometimes prevented the sea ice around Ulukhaktok from completely freezing over, resulting in open water and thin ice in areas that harvesters expect to be safe for travel (Rigor and others 2000; Environment Canada 2007). Experienced hunters explain that after two or three days with very cold (below -30°C) temperatures in the late fall (November), the sea ice used to freeze over and although it was thin, it could support travel by snow machine. In the past decade, however, the sea ice is taking longer to freeze over and

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Fig. 2. Inuit hunter, Adam Kolouhok Kudlak, retrieves a ringed seal *natiq* from the open water lead *aolagot* near Holman Island *Qikiktakyoak* using an open water boat *oinikhiot* on 20 February 2009.

recently there have been years when there has been open water and/or very thin unstable temporary ice cover that is vulnerable to winds and current (Fig. 2).

The speed and direction of the wind affects sea ice dynamics. Queen's Bay, where the community is located, faces southwest and a strong northeast wind is necessary to break up the sea ice, usually in the late spring. Northeast winds, however, are no longer exclusive to the spring and they have been experienced in recent years in the autumn and winter, resulting in later freeze-up, premature break-up and open water leads. Open water and unstable sea ice has made it more difficult for harvesters to reach autumn, winter, and spring hunting areas accessible by the sea ice. Harvesters must travel to other locations or take alternative travel routes that are often longer and require more time and fuel than the affected routes, and carry their own risks (for example land crossing) (see Current adaptive strategies).

Winds also affect sea ice break-up in the spring. Westerly winds have become more common in the spring which is a deviation from the usual pattern of east winds. In the spring of 2005, east winds broke up the ice in late May but the wind direction shifted to westerly winds which pushed the broken ice back into the community bays and prevented harvesters from travelling by boat. Harvesters were unable to access caribou harvesting grounds in Prince Albert Sound, *Kangiryuaq* until late in the fall. While these specific observations may be an aberration for the year, unpredictable wind patterns are increasingly being observed in the community indicating that a trend of changing wind patterns may be occurring.

Quality and availability of wildlife

Harvesters have observed changes in the quality and availability of some wildlife species important for subsistence. These changes are affecting subsistence and income driven activities that depend on quality wildlife products (for example sport hunting, food, furs for crafts and clothing). In the winter and spring of 2005, hunters observed a significant decline in the quality of ringed seals and in the number of young ringed seals caught (ringed seals are harvested in Ulukhaktok for their meat and pelts). The ringed seals harvested were extremely lean, the meat was often not suitable for human consumption, and the pelts held limited economic value. Although the community does not depend on seals for fuel, food, or income as they did in the past, seals are still harvested for dog food and a decline in the health of seals is interpreted as an indicator that the health of the ecosystem is under threat.

> This year was very real for the community because there's so many signs of running out of seals. The seals were in need of their own food chain and it wasn't around so therefore they were skinny. Anonymous (translated from Inuinnaqtun)
>
> Seals are very skinny through the spring, they are pitiful. . .we can't eat them because of health concerns. They are only good for dog food. Pat Ekpakohak, (translated from Inuinnaqtun)

The quality of ringed seal meat and pelts improved later in the summers of 2005 and in 2006. However, harvesters report a continued decline in the number of young ringed seals harvested.

An experienced seal hunter in Ulukhaktok who has hunted and worked extensively on seal monitoring projects in the region for over three decades explains that when the sea ice breaks up early, as it has in recent years, it is quickly blown out into the ocean and many young seals and adult animals are removed from the area. As a result, there are fewer seals in locations where they are expected to be abundant (H. Wright, personal communication, 1 December 2008). Others have recorded poor seal health and a potential association with changing sea ice conditions. In 1998, for instance, Smith and Harwood (2001) observed poor body conditions and short body lengths in a sample of neonate ringed seal pups in Prince Albert Sound (Ulukhaktok harvesting area). Although not defined, these conditions may have resulted from later birth dates or shortened lactation and consequent slower growth associated with the premature disruption of the land fast ice breeding habitat (Harwood and others 2000).

Beginning in the late 1970s, there has been a dramatic decline in the Peary caribou population on the Arctic islands. Caribou is an important and preferred source of meat in the community. Aerial surveys conducted by the government of the Northwest Territories (GNWT), found that the Minto Inlet caribou population (important to Ulukhaktok) declined from 4500 in 1980 to about 100 in 1993 (Nishi and Buckland 2000). Recent warming has led to a dramatic increase in the number of days above freezing temperatures during the migration period for the caribou, and thawing and freezing of snow results in ice layers in the snow pack that hinder travel of caribou and make it more difficult for them to forage for food. The formation of ice layers that prevent caribou from accessing food has been identified as a key causal factor of the declines (Russell 2007). Peary caribou are now

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Table 3. Current adaptive strategies and adaptation constraints.

Adaptive strategies	Descriptions	Adaptation constraints
Extra precautions	• Hunters are taking extra precautions when they travel: – Read environmental signs and weather forecasts before traveling – Travel with extra gas, fuel, food, and supplies – Travel closer to the community when there is the potential for an early spring melt – Travel in groups and leave travel itineraries behind – Travel with a VHF radio, satellite phone and/or GPSs	• High cost of gas, fuel, and supplies • Limited number of jobs, educational requirements, and nepotism make obtaining wage employment difficult • Changing levels of traditional environmental knowledge and land skills among youth • Substance abuse saps material resources and impairs decision making
Alternative transportation and travel routes	• Use alternative modes of transportation • Change travel routes, hunting locations, and techniques • Change species harvested • Wait in the community until hunting areas are accessible	• Inability to access capital resources is a barrier to purchasing needed harvesting equipment – e.g. boat, snow machine, ATV • Employment limits the timing and duration of harvesting activities
Food sharing and change in diet	• Share country foods • Change species harvested • Supplement diet with food from stores	• Not being able to harvest has social, cultural, and health implications • Store-bought food is expensive and less satisfying • Not everyone has the necessary transportation equipment or skills to change species harvested

listed as an endangered species in Canada, a species that faces imminent extirpation or extinction. In 1993, harvesters in Ulukhaktok implemented a voluntary five year moratorium on hunting Peary caribou from the Minto Inlet population. That moratorium ended in 1998 and is now reviewed annually, but since 1993 Ulukhaktok harvesters have only hunted caribou from the Dolphin-Union caribou population on the south part of Victoria Island (NWT Wildlife 2007). This requires travelling long distances by boat which limits who is able to participate in the harvest based on access to a boat, fuel, and time.

Current adaptive strategies

Inuit in Ulukhaktok have a long history of coping with change and are employing several measures to deal with current climate related exposure sensitivities. There are numerous characteristics by which adaptations can be distinguished and which could contribute to the development of a typology of adaptation (for example Burton and others 1993; Carter and others 1994; Smithers and Smit 1997). This analysis of adaptations draws on a modified set of adaptation characteristics described by Smit and Skinner (2002) and includes timing and duration, scale and responsibility, and degree of success. Timing differentiates adaptations based on whether they are anticipatory (pro-active), concurrent (during), or responsive (reactive); duration identifies adaptations according to the time frame over which they apply (for example tactical (short-term) vs. strategic (long-term)); scale distinguishes the spatial extent at which adaptation occurs; responsibility differentiates among the various actors that undertake or facilitate adaptations; and degree of success highlights how adaptation success is viewed differently by various agents. Adaptations that are deemed successful by some agents may have undesirable outcomes for others. These characteristics are applied in describing the adaptive strategies employed to deal with climate related exposure sensitivities in Ulukhaktok (Table 3).

Extra precautions

Community members often respond to climate related hazards by adjusting their behaviour without any pre-planned strategy (reactive). Harvesters react to increased variability and unpredictability in climate conditions, such as the occurrence of a storm or a sudden spring melt, by drawing on their knowledge of the local environment and the resources available to them to cope with the disturbance. For example, harvesters have coped with the onset of sudden storms by drawing on their knowledge of the local geography to find refuge and set up camp, have unexpectedly altered travel routes to avoid hazardous trail conditions, and have switched species harvested when necessary.

Reactive courses of action serve short term needs but have also contributed to the development of longer term proactive adaptations. Drawing on past experiences

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coping with climatic risks, harvesters are increasingly anticipating the possibility of encountering hazards when travelling on the land and sea ice, and are taking extra precautions to avoid and/or be prepared to cope with emerging risks. These precautions include: taking extra time to read environmental signs and local weather reports before travelling; travelling with extra supplies (for example gas, fuel, food, tent, etc.); travelling closer to the community when there is the potential for an early spring melt; travelling in groups; leaving travel itineraries with people in the community in case they encounter hazardous conditions and require assistance; and travelling with a VHF radio, satellite phone and/or GPS. There are several incidences of harvesters being stranded due to rapidly changing conditions (for example caribou hunters stranded in Prince Albert Sound because of bad weather or moving sea ice), but because they carried extra food, fuel and supplies they were able to cope with the situation and wait for conditions to improve before returning safely to the community. In other cases, having a VHF radio or satellite phone has enabled travellers, who became stuck in melting conditions, to contact people in the community for assistance.

Alternative transportation and travel routes

Harvesters have adapted to compromised travel routes to hunting areas by adjusting their modes of transportation, travel routes, and hunting locations. For example, in the event of an early break-up or late freeze-up (when travel on the sea ice by snow machine is not feasible) harvesters who have access to alternative transportation equipment have adapted and now travel to hunting areas by all terrain vehicles (ATV) or boat. Harvesters usually switch from travelling by ATV to snow machine in approximately mid October; however, in the past few years due to late snowfall, harvesters have been travelling inland by ATV until late November. The down side to this change is that it is more difficult to pull a sled, *alliak* behind an ATV and it cannot carry as much weight as it could if it were being pulled by a snow machine. In the marine environment motorised boats are becoming increasingly important for adapting to changing sea ice conditions and are being used to access hunting areas in the spring (for example duck hunting) and autumn (for example caribou hunting). The ocean around Ulukhaktok is often rough due to the prevalence of wind and boating can be a dangerous mode of transportation. Furthermore, hunting ducks from a boat is more difficult than by snow machine and requires more fuel.

> We hunt ducks in the spring. You need good ice to hunt ducks, go by [snow] machine. If it's an early break-up and the ice is bad we go by boats but it's harder to hunt ducks from the boat. The boat moves around and it's harder to shoot. . . Anonymous.

As a result of later sea ice freeze-up, harvesters are changing their travel routes. For instance, harvesters are travelling inland by snow machine rather than on the sea ice to reach caribou hunting areas in Prince Albert Sound. This route is not as desirable as moving on the sea ice because it is longer and more rugged. Similarly, as a result of more open water during the winter and spring, hunters have been forced to change their travel routes to key polar bear hunting areas. To hunt polar bears around Nelson Head, an important polar bear hunting area, hunters used to travel by snow machine across the sea ice in the Amundsen Gulf from Ulukhaktok to Banks Island. Within the past decade, this travel route has not been possible because the sea ice has not completely frozen over. To reach Nelson Head, harvesters have had to travel longer distances up the coast of Victoria Island, cross the sea ice in the Prince of Wales Strait *Ikirahak* near Ramsey Island to Banks Island and then travel along the coast of Banks Island to Nelson Head. This route takes longer and requires more fuel, and some hunters have opted to hunt in alternative locations. Several hunters do not have access to the transportation equipment or fuel needed for travelling via alternative routes, and others do not possess the environmental knowledge or land skills important for navigating new routes. This limits who is able to adapt to changing sea ice conditions and continue to participate in subsistence hunting.

Food sharing

Harvesters often share country foods with other people in the community. For example, in July 2005, a hunter was fortunate to harvest a lone Peary caribou. Upon returning to the community, the hunter divided the animal into separate portions and distributed them to 22 households in the community. Similarly, when a community member harvested a beluga whale *qilalugaq* (*Delphinapterus leucas*) during the same month, they also distributed the whale meat, *maktaq* throughout the community. This form of sharing *payuktuq* (the giving or carrying of food, whether fresh or cooked, to another individual or household) is documented by Collings and others (1998) to be the most frequent type of food sharing practiced in Ulukhaktok. Food sharing relationships have a long history in Inuit society, and as in the past, food sharing networks continue to help people cope during times when country foods are less abundant. An interviewee describes the importance of food sharing.

> . . .that's what community is all about, sharing. Once they share something today, with their family or elders . . . . people bring them some and share, they still do that, they do that like long ago when they catch something they share it. . .bring food to elders and people who can't get out. . .that is what I like about Holman [Ulukhaktok], people share, with their family or the elders. . . Susie Malgokak.

Food sharing provides community members with country foods in spite of factors that may affect their involvement in harvesting including changing climatic conditions. Food sharing is also part of a greater emotional and social bond that is built among individuals and which is important for a healthy community. Some respondents, however, report that food sharing networks are not functioning as they did in the past. Food sharing

is now more restricted to within family units. A detailed analysis of food sharing networks in the community is needed to understand better the distribution process in the context of continuing social and environmental changes.

Change in diet

Most community members supplement their diet, to varying degrees, with store bought foods. For many Inuit, however, store bought foods are not an equal trade off for country foods. Store bought foods are considered to be less satisfying, not as desirable, and more expensive. This finding is consistent with research on Inuit dietary beliefs and attitudes (Condon 1995; Wenzel 1995; Wein and others 1996; Collings and others 1998). As described in Collings and others (1998) and substantiated in community interviews, country foods are preferred because they are healthier, fresher, and therefore better tasting and more satisfying, and less expensive than store foods. A respondent who is faced with purchasing more store bought foods to feed his or her family due to a combination of factors including less time to participate in harvesting activities due to employment, increased costs associated with harvesting (for example equipment and fuel), and changing climate conditions, describes what it is like not to have country (native) foods.

> . . .we have a lot of native food and once you don't have a certain type of food, it's like you're always hungry even though you eat, and once you finally have that certain type of food it's like your body is satisfied, your not as hungry all the time, but I could see that happening more and more in the future if the weather keeps changing the way it is, I could see us craving for more and more native food. Anonymous.

The collection and consumption of country foods is also important to cultural identity. The importance lies in the activity of harvesting, spending time with family members, the fulfilment, status, and self-esteem associated with the harvest and also in the sharing of country foods.

> When people want to travel and weather patterns change like this, it affects their emotions, their mentality. They live on country food. It is good for their soul and to spend time with family members. Jimmy Memogana (translated from Inuinnaqtun).

Adaptation success in this case is a matter of perspective and, although it is feasible that a community household could survive on store bought foods, it is not a desirable option for many community members, and has broad social, cultural, and health and nutritional implications. This highlights the importance of engaging local peoples in adaptation planning to ensure that policies reflect the values and needs of the community.

Adaptation constraints

There have been rapid societal changes in Arctic regions in the last half of the twentieth century. These have included: settlement of semi-nomadic groups in permanent communities; the development of the wage economy; compulsory schooling; participation in external markets; imposition of wildlife management such as hunting quotas; rapid population growth; and land claim agreements (Wenzel 1991; Hamilton 1994; Oakes and Riewe 1997; Damas 2002). These changes have affected harvesting practices, social networks, and cultural and spiritual traditions, and have been linked to the loss of land skills among youth and to social problems (Kral 2003; Einarsson and others 2004; Takano 2005). In several instances, social change and climate change have acted synergistically to affect Inuit livelihoods and adaptive capacity. The interconnections between access to capital resources, the development of the wage economy, changing levels of traditional knowledge and land skills among youth, substance abuse and adaptive capacity to deal with climate change are discussed here (Table 3).

Access to capital resources

Harvesters depend on mechanised modes of transportation to access hunting areas. Snow machines have all but replaced dog teams as the primary mode of transportation in the winter and spring, ATVs are the vehicle of choice for travel on the land in the summer and autumn, and motorised boats are used on the ocean. Mechanised transportation allows harvesters to access hunting areas beyond the limited zone imposed by fixed settlements. In some instances, changing trail conditions have made it necessary for harvesters to switch their mode of transportation and travel longer distances to access hunting areas. Transportation technology, however, is expensive to purchase, maintain and operate, and the price of fuel has increased dramatically in recent years (the price of petroleum in Ulukhaktok was $1.77 CDN/litre on 26 November 2008). This limits who is able to participate in harvesting, a problem that is exacerbated by emerging climatic changes.

Community members face significant challenges in obtaining capital resources including a limited number of wage jobs, lack of qualifications, and nepotism in the local workforce. Several adults who moved from a subsistence lifestyle on the land into the permanent settlement have limited formal education and even though they often possess the necessary skills, they are not academically qualified for many wage jobs that require a high school education. In 2004, 49% of adult community members had less than a high school education (NWT Statistics 2006). Furthermore, some high school graduates in Ulukhaktok have been assessed at education levels much lower than their granted grade twelve diploma; as a result, these individuals do not have the credentials to pursue higher education or to obtain skilled employment in the community without additional upgrading. Concerns about the standard of education provided in communities in the Canadian Arctic are well documented (Irwin 1989; Berger and Epp 2005; Johansson and others 2005).

In some cases, community members choose not to seek employment, a consequence of the NWT housing rental policy that bases rent on an assessment of household income (33% of household income goes towards rent)

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(NWT Housing 2006). Depending on their income level renters can pay up to $2,617 CDN per month for a four bedroom rental house whereas renters who receive income support only pay $32.00 CDN per month (NWT Housing 2009). Some community members lack the incentive to seek employment because a large percentage of their income will go to paying rent, a cost they can avoid by not working. These factors affect participation in harvesting and constrain adaptations that require capital resources.

A regional scale programme, the Inuvialuit harvesters assistance program (IHAP) responds to this need and provides some Inuit with funding to purchase harvesting equipment. Preference is given to Inuvialuit subsistence harvesters engaged in harvesting activities and showing demonstrated need for programme support to continue or start harvesting and, those harvesting applicants that regularly involve youth in their traditional harvesting activities (IRC and IGC 2001). For the IHAP a subsistence harvester is defined as an Inuvialuit harvester who is either currently or has been within the last three years, active for six or more months of the year in hunting, fishing and trapping activities for subsistence purposes (IRC AND IGC, 2001). Applicants to IHAP are eligible to receive up to $5000 CDN once every three years towards the purchase of new harvesting equipment. IHAP is not directed at adaptation to climate change, but builds household capacity to participate in harvesting. In Ulukhaktok, IHAP has provided successful applicants with the economic means to purchase new transportation equipment, which has enabled them to continue to harvest, and in some cases be better equipped to deal with changing conditions. Four interviewees identified IHAP funding as essential for their households to be able to participate in subsistence. One couple that has three children explain that IHAP funding enabled them to purchase a new snow machine and they are now once again able to travel in the winter and spring to go fishing and duck hunting. However, several respondents commented that the allocation of IHAP in the community is plagued by nepotism and funds were not necessarily being allocated to individuals who met the programme's definition of 'subsistence harvester' (defined above). Addressing this concern to ensure that IHAP funds are allocated to subsistence harvesters and then potentially expanding the IHAP programme to assist more harvesters are practical initiatives that would support involvement in harvesting under changing conditions.

Availability of time

Some community members balance harvesting with the wage employment necessary for generating income to purchase harvesting equipment, supplies, and fuel. Employment, however, also constrains the timing and duration of harvesting activities. Unpredictable weather patterns and increasingly compromised travel routes have made it difficult to plan when to travel on the land, and employment obligations further limit when harvesters can travel. Consequently, some employed harvesters, although well equipped for harvesting, are spending less time harvesting and are making shorter, rushed trips to travel when conditions are not considered optimal. Three male respondents who have full time wage employment in the community explain that because of employment obligations they are spending less time harvesting than they did prior to working in the wage sector. When asked whether they used their days off and vacation time to harvest, each respondent replied that while they did use some of their time off for harvesting, they most often spent their days off relaxing in the community. Two of these respondents said that they sometimes choose not to travel on their days off because of uncertainty if they would make it back to the community in time for their next work day. Employment acts as both an aid to adaptation by providing access to a needed source of income, but it can also constrain adaptation by limiting the timing and duration of harvesting activities. An analysis of the relationship between employment and participation in subsistence harvesting is available in Condon and others (1995).

Traditional knowledge and land skills

Inuit capacity to deal with variable environmental conditions has long been facilitated by traditional environmental knowledge and land skills. The term 'traditional knowledge' is defined as a cumulative body of knowledge, practice and values, which have been acquired through experience, observation from the land or from spiritual teachings, and handed down from one generation to another (Huntington 1998; Berkes 1999; Government of the Northwest Territories 2005). Traditional knowledge is dynamic, continually evolving and being updated, and has evolved in this context to manage changing climatic conditions, including unpredictability and extremes. Hunters manage the risks associated with hunting by taking precautions, knowing what equipment to take along and what preparations to make, and being sensitive to critical signs in the environment and knowing how to respond. Knowledge of animal behaviour enables hunters to adapt to changing animal numbers and location.

Traditionally, knowledge and skills were developed and transmitted through on-the-land education or 'people's practical engagement with the environment. . .' (Ingold and Kurttila 2000), and from listening to and learning from elders and other experienced individuals. In traditional Inuit education, learning and living were the same thing, and knowledge, judgment and skill could never be separated (Nunavik Education Task Force 1992). However, community members are concerned that the traditional modes of intergenerational knowledge transfer and learning by which Inuit have developed the skills to hunt safely and successfully no longer function effectively. Elders and other experienced community members together with community educators, point to the potential loss of land based skills coupled with lack of workplace relevant skills among the growing population of young Inuit (49% of the population in Ulukhaktok is

under the age of 25 (NWT Statistics 2006)). Youth are spending considerably less time involved in traditional subsistence activities beyond organised land camps and occasional hunting trips but comparatively more time engaged in formal education and wage employment. Adult community members are concerned that youth are not learning the land skills necessary for safe and successful harvesting, particularly in light of the changes they are experiencing in the climate and environment.

> Young people go out on the land in everyday jackets; they get cold more easily; they go for appearance. They can't go for long periods of time, can't take the cold anymore. [They] get stranded on the land, they can't make snow shelters and searches have to go for them. . .older adults should be taking out young people, teaching them survival on the land. Ida Kuneyuna (translated from Inuinnaqtun).

It is widely accepted in the community that some form of formal education is necessary and beneficial; however, there is strong support for youth to receive a more balanced education between formal school teachings and land based skills. It is not expected that youth should return to the traditional lifestyle that their elders lived, but there is an expressed need for youth to have sufficient knowledge of the land and harvesting activities if the values and benefits integral to a subsistence lifestyle are to be carried forward to future generations.

Substance abuse

Substance abuse was identified as a major stress affecting the community. Although there is no legal distributor of alcohol in Ulukhaktok, community members can order alcohol from Yellowknife or Inuvik as freight. Drugs, primarily marijuana, is also readily accessible in the community. Substance abuse has led to addictions, health problems (for example foetal alcohol syndrome), family violence, child neglect, and the disruption of social networks.

> Right now there is so much drug and alcohol problems in the community. . . [It is] probably the biggest problem that we have in the community. . .kids [are] going hungry because their parents spend their money on drugs and alcohol, there are more fights, more stress in families. Anonymous.

At the time of the research the drug and alcohol counsellor, wellness worker and mental health worker positions in the community were vacant, and if needed, community members had to fly to Inuvik for these services. These wellness positions often go through rapid rotations of southern workers and some positions go unfilled for years at a time. Addictions and lack of support services have left some community members more susceptible to stresses associated with substance abuse, and consequently ill prepared to deal with challenges that may arise from climate change, sapping both their material resources and impairing decision making (for example money is spent on drugs and alcohol instead of on needed harvesting equipment, supplies, fuel, or food and in some cases harvesting equipment has been traded for drugs and/or alcohol).

Future vulnerability

Exposure sensitivities and adaptive capacity are dynamic and will change as the community and the climate change over time. Harvesters in Ulukhaktok are currently sensitive to climate related risks that make harvesting more hazardous, compromise travel routes to hunting areas, and affect the health and availability of wildlife species important for subsistence. These conditions are projected to continue in the future with further implications for Inuit livelihoods. It is not possible to predict the future with certainty, but we can gain insight into the nature of future vulnerabilities by using current exposure sensitivities and adaptive strategies as starting points from which to consider the implications of projected changes in climate and society (Ford and others 2006).

Climate models generally estimate future changes in climate over specified time periods (for example 10, 50, 100 years). These estimations are useful for understanding potential future changes in temperature and precipitation and their associated affects (for example sea ice extent and thickness, permafrost, etc.). This section includes information from future climate models; however, it does not focus on specific future time periods but rather deals with the progression of current exposure sensitivities and adaptive capacity relative to anticipated changes in climate and society.

Future exposure sensitivities

Depending on the model and forcing scenario used, the average warming in the Arctic is projected to range from about 2°C to about 9°C by the year 2100. The projected warming is largest in the autumn and winter, and is largest over the polar oceans in areas of sea ice loss (Anisimov and others 2007). A study based on the IPCC model simulations and scenarios, projects mean reductions of annually averaged sea ice area in the Arctic by 2080–2100 of between 22% and 33% depending on the atmospheric greenhouse gas loading scenario used (Zhang and Walsh 2006). Other studies project an ice free Arctic ocean in September within this century (Stroeve and others 2007). Climate models generally agree that likely impacts of future warming will also include changes in the timing and duration of the spring melt season (Rigor and others 2000), increased precipitation (Kattsov and others 2007), later freeze-up and earlier break-up of river and lake ice (Walsh 2005) and an increased frequency of extreme weather and storm events (Kattsov and Kallen 2005). These projections, although not inclusive of all possible changes that may occur as a result of climate change, present a range of possible future risks for arctic communities. Table 4 outlines some potential implications of future climatic changes in Ulukhaktok based on current community-identified exposure sensitivities.

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Table 4. Future climate change projections and possible future exposure-sensitivities.

Exposure sensitivities	Future climate change projections	Future exposure sensitivities
Increased travel risks	• Reduction in sea ice cover and volume (Loeng 2005; Arzel and others 2006; Stroeve and others 2007)	• Travel on the sea ice could become more dangerous particularly in the autumn and spring
Compromised travel routes	• Longer melt season (Rigor and others 2000; Smith 1998) • Later freeze-up and earlier break-up of river and lake ice (Walsh 2005) • Increased precipitation in the spring (Kattsov and Kallen 2005) • Increased frequency of extreme climate events (Kattsov and Kallen 2005)	• Increased risk of becoming stuck/stranded in melting conditions • Reduced access to spring harvesting areas (e.g. fishing at inland lakes) • Dangerous if travelers are not prepared for wet conditions • Could make travel more dangerous and harvesting more difficult (for example risk of being separated from travel party) • Rough sea ice is difficult and sometimes not suitable to travel on • Less time spent on the land – erosion of traditional land skills among youth
Quality and availability of wildlife	• Decline in polar bear population and health (Derocher and others 2004; Stirling and Parkinson 2006) • Decline in ringed seal population and health (Harwood and others 2000; Smith and Harwood 2001)	• Loss of income from sport hunting and the sale of furs and pelts • Less country foods • Less food for sled dogs (seal)

Projected reductions in sea ice cover, more unstable sea ice conditions (for example thin ice), and trends toward later freeze-up and earlier break-up would probably continue to exacerbate risks associated with travel on the sea ice, compromise travel routes to hunting areas, and affect the health and availability of some wildlife species. Some species of marine wildlife that are harvested by Ulukhaktok hunters, specifically ringed seals and polar bear, are expected to be negatively affected by projected increases in precipitation and changes in sea ice (Loeng 2005; Laidre and others 2008). A study of the ringed seal population around Ulukhaktok documented that even a very local, small scale, premature disruption of the land fast breeding habitat has significant negative impacts on the growth, condition and survival of unweaned pups (Harwood and others 2000). Progressively warmer temperatures in spring will cause seal birth lairs to melt earlier, exposing pups at increasingly earlier ages to predation and freeze thaw cycles similar to those recorded by Stirling and Smith (2004). Projected increases in precipitation in the spring are expected to result in more frequent and widespread collapses of subnivean birth lairs, the mortality of ringed seal pups will increase and local populations may be significantly reduced. As ringed seals are the primary prey of polar bears, a significant decline in ringed seal populations, especially in the production of young, is capable of having negative effects on the health of polar bears (Stirling and Parkinson 2006).

Polar bear hunting is an important activity in Ulukhaktok for subsistence and as a source of income. Several hunters in Ulukhaktok derive a large portion of their income from guiding and helping on sport hunts for polar bear. Climate and political changes, however, have implications for polar bears and the sport hunting industry in the Canadian Arctic. The health of the polar bear as a species under future climate change projections is in question. Stirling and Parkinson (2006) and Stirling and others (1999) documented a significant positive relationship between the time of sea ice break-up and the condition of adult female polar bears (that is the earlier the break-up, the poorer the condition of the bears). Strong positive relationships between the time of sea ice break-up and freeze-up have also been documented by Derocher and others (2004), who found that reduced sea ice has led to reduced reproductive rates. Scientists have expanded these findings to the whole circumpolar Arctic and suggest that polar bears are threatened as a species if future sea ice projections of a complete disappearance of sea ice in the Arctic Ocean during the summer, come true (Derocher and others 2004). Dyck and others (2007), however, warn that claims for the fate of polar bears are highly premature. They challenge the skilfulness of climate models to project sea ice changes and argue that alternative factors including, increased human-bear interaction, natural population dynamics, and variability of the Arctic ice, ocean and atmosphere that occur naturally on decadal to multi-decadal time scales must be taken into account in a more realistic study and explanation of the population ecology of polar bears.

Together with climate change, political changes threaten the polar bear sport hunting industry in the Canadian Arctic. Despite assurances from Inuit and

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wildlife biologists in the NWT and Nunavut that most polar bear populations are healthy and in some regions increasing, the United States government has decided to list polar bears as a threatened species under its endangered species act because of the effects of climate change. The endangered species designation bans all polar bears products from being imported to the US, including the trophy hides that most sport hunters seek, essentially shutting down the American component of the Canadian polar bear sport hunting industry. The implications of this ban on Inuit hunters has yet to be determined.

Future adaptive capacity

Consistent with current adaptive capacity, the future capacity of community members to deal with climate change will probably depend on factors including access to capital resources, community wellness, and the transmission of traditional knowledge and land skills. In several cases, supporting current adaptation needs will enhance adaptive capacity to deal with projected future changes.

Access to income

Adaptations that necessitate economic responses (for example extra fuel, alternative mode of transportation, purchasing food from stores) could be supported by developing income generating opportunities. Efforts have been made and are currently underway in Ulukhaktok to provide community members who are seeking employment with additional skills training and greater educational opportunities. Programmes include education in the community extending to grade 12, and courses at the local Aurora College campus that focus on skills training pertinent to current employment opportunities in the community and region (for example exploration geology, oil and gas industry, driver's licence, small business operation, environmental monitoring). As a result of these efforts, more community members are obtaining their high school education which should make them eligible for more employment opportunities, and community members are obtaining job related skills that allow them to work on projects such as mineral exploration. Despite these advancements in training respondents express the need to offer more programmes that are of interest to community members beyond those provided by current industrial interests (for example mineral exploration and oil and gas development), and that meet the educational competency standards necessary for students to pursue post-secondary education. Some respondents, including local educators and high school graduates, call for educational reform to develop a curriculum that meets both southern educational requirements and also includes traditional knowledge, land skills, Inuinnaqtun language, and cultural values that are important to the community. They argue that if education had a better balance between southern curriculum and traditional knowledge and land skills, more people would value the opportunities education presents and more fully engage in educational pursuits.

Potential future resource development (mining and/or oil and gas development) would certainly influence future vulnerability. Increases in individual incomes, seasonal employment patterns, greater exposure to outside cultures, and divisions in the community between those in favour of development and those opposed are potential factors to consider, the implications of which have been documented elsewhere in the Canadian Arctic (Brubacher and Associates 2002). Currently there is no resource extraction activity near the community, but two companies, Great Northern Mining and Exploration and DeBeers are actively exploring Inuvialuit lands on Victoria Island for precious metals and diamonds and the Mackenzie Valley gas project is currently under review.

Flexibility

There is some uncertainty when discussing future climate change projections but community members recognise that continued flexibility and ingenuity will play central roles in future adaptation.

> I could see us having to learn all over again about the ice conditions in the spring time, the ice conditions in the early fall or winter with the climate change and the way it's affecting it. I think we're going to have to be like educated all over again on how to travel or when to travel, good time of the year to travel. Anonymous.

Flexibility may be expressed in an individual's ability to use alternative modes of transportation and alternative travel routes to access hunting areas, and/or change the timing and location of harvesting as well as the species of wildlife harvested. Knowledge of the local environment and land skills influence how harvesters respond and adapt to changing environmental conditions. These skills are honed through consistent interaction with the environment. Programmes that support participation in harvesting activities and the transmission of environmental knowledge and land skills to youth are important for ensuring that younger generations have the opportunity to learn and practice these skills. Additional support for land programmes operated by the school, hamlet and Canadian rangers, and for programmes that connect elders with youth would contribute to the transmission of knowledge and skills and build capacity among younger generations to cope with and adapt to changing environmental conditions.

Flexibility may also be found at the institutional level in terms of comanagement bodies that facilitate communication between the community, the regional Inuvialuit government, the territorial government and the federal government. Membership in comanagement bodies such as the fisheries joint management committee (FJMC), and the wildlife management advisory council (WMAC) provide Ulukhaktok with access to scientific information and additional resources to address issues affecting the system or species of interest. The ability of these institutions to be flexible and include climate change impacts and projections in environmental and other assessments and to be innovative in their response

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strategies, will contribute to adaptive capacity to deal with future climate change.

Discussion

In the literature on climate change impacts and adaptation in the Arctic, this study aims to represent a significant contribution by showing how people in communities are affected by and are responding to conditions associated with a changing climate. The research investigated human vulnerabilities to climate change in the community of Ulukhaktok. Vulnerability is conceptualised as a function of both the characteristics of climate which the community is exposed and sensitive to, and the capacity of the community to adapt. The knowledge and experiences of local people were primary sources of information, and the involvement of community members in the research provided an opportunity to identify climate conditions and adaptations that were important to community members beyond those selected a priori by researchers. It also allowed for the identification of multiple drivers of cumulative change which may not be climate related but influence how climate change is experienced and how adaptations are facilitated.

In Ulukhaktok, climate change together with changing livelihoods has altered, and in some cases exacerbated the exposure sensitivity of community members to climate driven hazards. In several ways, community members are more sensitive to existing and/or new risks associated with harvesting, travel routes to hunting areas have been compromised, and the health and availability of some wildlife species important for subsistence have been affected. Some community members are demonstrating significant adaptability to changing conditions. This adaptability is facilitated by access to capital resources, traditional knowledge and land skills, resource use flexibility, and strong social networks. The capacity to cope with and adapt to changing conditions, however, is not uniform among community members with some individuals better equipped to adapt than others nor are all adaptation options desirable. Societal factors including the inability to access capital resources, time restrictions imposed by wage employment, changing levels of traditional knowledge and land skills among youth and substance abuse are affecting the capacity of community members to deal with exposure sensitivities. These constraints to adaptation represent strategic policy entry points in which to address the adaptation needs of the community now and to enhance the adaptive capacity of the community in the future. As is the case with the IHAP providing economic support to community members to purchase harvesting equipment, adaptations to climate change are unlikely to be undertaken for climate change alone but are more likely to be a response to problematic conditions that already exist in the community. Supporting efforts that increase financial, health, educational, and cultural capacity in the community will inadvertently enhance the adaptive capacity of the community to deal with current and future climate change risks. Some of the experiences with climate change documented for Ulukhaktok are similar to those recorded elsewhere in the Arctic (for example Berkes and Jolly 2002; Ford and others 2008b) and some findings have been compared among communities in different regions (Gearheard and others 2006; Ford and others 2008a). An International Polar Year project, 'Community adaptation and vulnerability in Arctic regions (CAVIAR),' is building upon existing vulnerability to climate change research (including the research presented here) to draw comparisons among communities across the circumpolar Arctic, to understand better how arctic communities are affected by climate change, and identify common factors that influence exposure sensitivity and adaptation to help inform adaptation planning.

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References

ACIA (Arctic Climate Impact Assessment). 2005. *Arctic climate impact assessment scientific report*. Cambridge: Cambridge University Press.

Adger, N. 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *World Development* 27(2): 249–269.

Adger, N. 2006. Vulnerability. *Global Environmental Change* 16(3): 268–281.

Adger, N., and P. Kelly. 1999. Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change* 4: 253–266.

Adger, N., P. Kelly, and N. Ninh. 2001. *Living with environmental change: social vulnerability, adaptation and resilience in Vietnam*. London: Routledge.

Akoakhion, A. 2005. Interview. Ulukhaktok, 13 August 2005.

Alikamik, B. 2005. Interview. Ulukhaktok, 4 August 2005.

Anisimov, O., D. Vaughan, T. Callaghan, C. Furgal, H. Marchant, T. Prowse, H. Vilhjalmsson, and J. Walsh. 2007. Polar regions (Arctic and Antarctic). In: Parry, M.L., O. Canziani, J. Palutikof, P. van der Linden, and C. Hanson (editors). *Climate change 2007: impacts, adaptation and vulnerability*. Cambridge: Cambridge University Press (Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change): 653–685.

Aurora Research Institute. 2004. *Doing research in the Northwest Territories: A guide for researchers*. Inuvik: Aurora Research Institute.

Arzel, O., T. Fichefet, and H. Goose. 2006. Sea ice evolution over the 20th and 21st centuries as simulated by current AOGCMs. *Ocean Modeling* 12(3–4): 401–415.

Belliveau, S., B. Smit, and B. Bradshaw. 2006. Multiple exposures and dynamic vulnerability: evidence from the grape industry in the Okanagan Valley, Canada. *Global Environmental Change* 16: 364–378.

Berger, P., and J. Epp. 2005. 'There's no book and there's no guide': the expressed needs of Qallunaat educators in Nunavut. *Brock Education* 15(1): 13.

Berkes, F. 1999. *Sacred ecology: traditional ecological knowledge and resource management*. Philadelphia: Taylor and Francis.

Berkes, F., and D. Jolly. 2002. Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. *Conservation Ecology* 5(2): 1–18.

Bernard, R. 2000. *Social research methods: qualitative and quantitative approaches*. Thousand Oaks, California: Sage Publications Inc.

Brooks, N. 2003. *Vulnerability, risk and adaptation: a conceptual framework*. Norwich: Tyndall Centre for Climate Change Research (working paper 38).

Brown, R. 2000. Northern hemisphere snow cover variability and change, 1915–97. *Journal of Climate* 13: 2339–2355.

Brubacher and Associates. 2002. *The Nanisivik legacy in Arctic Bay: a socio-economic impact study*. Ottawa: Government of Nunavut, Department of Sustainable Development.

Burton, I., S. Huq, B. Lim, O. Pilifosova, and E. Schipper. 2002. From impacts assessment to adaptation priorities: the shaping of adaptation policy. *Climate Policy* 2(2–3): 145–159.

Burton, I., R. Kates, and G. White. 1993. *The environment as hazard*. New York: Guildford Press.

Callaghan, T. 2005. Arctic tundra and polar desert ecosystems. In: Symon, C. (editor). *Arctic climate impact assessment (ACIA) scientific report*. Cambridge: Cambridge University Press: 243–352.

Carter, T., M. Parry, H. Harasawa, and S. Nishioka. 1994. *IPCC technical guidelines for assessing climate change impacts and adaptations with a summary for policy makers and a technical summary*. London: University College, London, Department of Geography; Japan: National Institute for Environmental Studies Centre for Global Environmental Research.

Collings, P., G. Wenzel, and R. Condon. 1998. Modern food sharing networks and community integration in the central Canadian Arctic. *Arctic* 51(4): 301–314.

Condon, R. 1987. *Inuit youth: growth and change in the Canadian Arctic*. New Brunswick, NJ: Rutgers University Press.

Condon, R., P. Collings, and G. Wenzel. 1995. The best part of life: subsistence hunting, ethnicity and economic adaptation among young adult Inuit males. *Arctic* 48(1): 31–46.

Cruikshank, J. 2001. Glaciers and climate change: perspectives from oral tradition. *Arctic* 54(4): 377–393.

Cutter, S. 1996. Vulnerability to environmental hazards. *Progress in Human Geography* 20(4): 529–539.

Cutter, S., B. Boruff, and W. Shirley. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly* 84(2): 242–261.

Damas, D. 2002. *Arctic migrants/Arctic villagers*. Montreal: McGill-Queens University Press.

Derocher, A., N. Lunn, and I. Stirling. 2004. Polar bears in a warming climate. *Integrative and Comparative Biology* 44: 163–176.

Downing, T., and A. Patwardhan. 2003. Assessing vulnerability for climate adaptation. In: Lim, B., and E. Spanger-Siegfried (editors). *Adaptation policy frameworks for climate change: developing strategies, policies, and measures*. Cambridge: Cambridge University Press: 67–90.

Duerden, F. 2004. Translating climate change impacts at the community level. *Arctic* 57(2): 204–212.

Duerden, F., and E. Beasley. 2006. Assessing community vulnerabilities to environmental change in the Inuvialuit region. In: Riewe, R., and J. Oakes (editors). *Climate change: linking traditional and scientific knowledge*. Winnipeg and Quebec City: University of Manitoba Aboriginal Issues Press and ArcticNet: 81–93.

Dunn, K. 2000. Interviewing. In: Hay, I. (editor). *Qualitative research methods in human geography*. Victoria, Australia: Oxford University Press: 50–81.

Dyck, M., W. Soon, R. Baydack, D. Legates, S. Baliunas, T. Ball, and L. Hancock. 2007. Polar bears of western Hudson Bay and climate change: are warming spring air temperatures the 'ultimate' survival control factor? *Ecological Complexity* 4(3): 73–84.

Einarsson, N., J.N. Larsen, A. Nilsson, and O.R. Young (editors). 2004. *Arctic human development report*. Akureyri: Stefansson Arctic Institute.

Environment Canada. 2007. Daily data report for September 1979 to August 2007, Ulukhaktok, Northwest Territories. URL: http://www.climate.weatheroffice.ec.gc.ca/.

Eriksen, S., K. Brown, and P. Kelly. 2005. The dynamics of vulnerability: locating coping strategies in Kenya and Tanzania. *The Geographical Journal* 171(4): 287–305.

Fast, H., J. Mathias, and O. Banias. 2001. Direction toward marine conservation in Canada's western Arctic. *Ocean and Coastal Management* 44: 183–205.

Ferguson, M., and F. Messier. 1997. Collection and analysis of traditional ecological knowledge about a population of Arctic tundra caribou. *Arctic* 50(1): 17–28.

Fienup-Riordan, A. 1999. Yaqulget qaillun pilartat [What the birds do]: Yup'ik Eskimo understanding of geese and those who study them. *Arctic* 52(1): 1–22.

Nunavik Education Task Force. 1992. *Final report of the Nunavik educational task force*. Lachine, Quebec.

Ford, J. in press. Vulnerability of Inuit food systems to food insecurity as a consequence of climate change: A case study from Igloolik, Nunavut. *Regional Environmental Change*.

Ford, J., B. Gough, G. Laidler, J. MacDonald, K. Qrunnut, and C. Irngaut. 2009. 'Where's the ice gone?': Sea ice, climate change, and community vulnerability in northern Foxe Basin, Canada. *Climate Research* 37: 138–154.

Ford, J., J. Macdonald, B. Smit, and J. Wandel. 2006a. Vulnerability to climate change in Igloolik, Nunavut: what we can learn from the past and present. *Polar Record* 42(221): 127–138.

Ford, J., T. Pearce, J. Gilligan, B. Smit, and J. Oakes. 2008a. Climate change and hazards associated with ice use in Northern Canada. *Arctic, Antarctic and Alpine Research* 40(4): 647–659.

Ford, J., T. Pearce, B. Smit, J. Wandel, M. Allurut, K. Shappa, H. Ittusujurat, and K. Qrunnut. 2007. Reducing vulnerability to climate change in the Arctic: the case of Nunavut, Canada. *Arctic* 60(2): 150–166.

Ford, J., and B. Smit. 2004. A framework for assessing the vulnerability of communities in the Canadian Arctic to risks associated with climate change. *Arctic* 57(4): 389–400.

Ford, J., B. Smit, and J. Wandel. 2006b. Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada. *Global Environmental Change* 16(2): 145–160.

Ford, J., B. Smit, J. Wandel, M. Allurut, K. Shappa, H. Ittusujurat, and K. Qrunnut. 2008b. Climate change in the Arctic: current and future vulnerability in two Inuit communities in Canada. *The Geographical Journal* 174(1): 45–62.

Fox, S. 2004. When the weather is uggianaqtuq: linking Inuit and scientific observations of recent environmental change in Nunavut, Canada. Unpublished PhD dissertation, University of Colorado at Boulder. Department of Geography.

Furgal, C., and T. Prowse. 2008. Northern Canada. In: Lemmen, D., F. Warren, J. Lacroix, and E. Bush (editors). *From impacts to adaptation: Canada in a changing climate 2007*. Ottawa, ON: Government of Canada: 57–118.

Furgal, C., and J. Seguin. 2006. Climate change, health, and vulnerability in Canadian northern aboriginal communities. *Environmental Health Perspectives* 114(12): 1964–1970.

Fussel, H.M. 2007. Vulnerability: a generally applicable conceptual framework for climate change research. *Global Environmental Change* 17: 155–167.

Gearheard, S., W. Matumeak, I. Angutikjuaq, J. Maslanik, H.P. Huntington, J. Leavitt, D.M. Kagak, G. Tigullaraq, and R.G. Barry. 2006. 'It's not that simple': a collaborative comparison of sea ice environments, their uses, observed changes, and adaptations in Barrow, Alaska, USA, and Clyde River, Nunavut, Canada. *AMBIO: A Journal of the Human Environment* 35(4): 203–211.

George, J.C., H.P. Huntington, K. Brewster, H. Eicken, D.W. Norton, and R. Glenn. 2004. Observations on shorefast ice failures in Arctic Alaska and the responses of the Inupiat hunting community. *Arctic* 57(4): 363–374.

Government of the Northwest Territories. 2005. *Policy: traditional knowledge*. Yellowknife: Government of the Northwest Territories.

Hamilton, J. 1994. *Arctic revolution: social change in the Northwest Territories, 1935–1994*. Toronto: Dundurn Press.

Hare, W., and M. Meinshausen. 2006. How much warming are we committed to and how much can be avoided? *Climate Change* 75(1–2): 111–149.

Harwood, L., T. Smith, and H. Melling. 2000. Variation in reproduction and body condition of the ringed seal (*Phoca hispida*) in western Prince Albert Sound, NT, Canada as assessed through a harvest-based sampling program. *Arctic* 53(4): 422–439.

Huntington, H. 1998. Observations on the utility of the semi-directed interview for documenting traditional ecological knowledge. *Arctic* 51(3): 237–242.

Huntington, H., and S. Fox. 2005. The changing Arctic: indigenous perspectives. In: Symon, C. (editor). *Arctic climate impact assessment (ACIA) scientific report*. Cambridge: Cambridge University Press: 62–95.

Huntington, H., L.C. Hamilton, C. Nicolson, R. Brunner, A. Lynch, A.E.J. Ogilvie, and A. Voinov. 2007. Toward understanding the human dimension of the rapidly changing Arctic system: insights and approaches from five HARC projects. *Regional Environmental Change* 7(4): 173–186.

Huq, S., A. Rahman, M. Konate, Y. Sokona, and H. Reid. 2003. *Mainstreaming adaptation to climate change in least developed countries*. London: International Institute for Environment and Development (IIED) climate change programme.

Ingold, T., and T. Kurttila. 2000. Perceiving the environment in Finnish Lapland. *Body and Society* 6: 183–196.

Instanes, A. 2005. Infrastructure: buildings, support systems, and industrial facilities. In: Symon, C. (editor). *Arctic climate impact assessment (ACIA) scientific report*. Cambridge: Cambridge University Press: 907–944.

IPCC (Intergovernmental Panel on Climate Change). 2001. Climate change 2001: impacts, adaptation, and vulnerability. Cambridge: Cambridge University Press (Contribution of working group II to the third assessment report of the Intergovernmental Panel on Climate Change).

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate change 2007: impacts, adaptation and vulnerability. Cambridge: Cambridge University Press (Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change).

Irwin, C. 1989. Lords of the Arctic: wards of the state. The growing Inuit population, Arctic resettlement and their effects on social and economic change – a summary report. *Northern Perspectives* 17(1): 2–12.

IRC and IGC (Inuvialuit Regional Corporation and Inuvialuit Game Council). 2001. Inuvialuit harvesters assistance program policy and procedures manual. Inuvik: Inuvialuit Regional Corporation and Inuvialuit Game Council.

ITK and NRI (Inuit Tapiriit Kanatami and Nunavut Research Institute). 2007. *Negotiating research relationships with Inuit communities: a guide for researchers*. Iqaluit and Ottawa: Inuit Tapiriit Kanatami, Nunavut Research Institute.

Johansson, G., C. Paci, and S. Stenersen-Hovdenak. 2005. Education. In: Einarsson, N., J. Larsen, A. Nilsson, and O. Young (editors). *Arctic human*

development report. Akureyri: Stefansson Arctic Institute: 169–185.

Jones, R. 2001. An environmental risk assessment/management framework for climate change impacts assessment. *Natural Hazards* 23: 197–230.

Kasperson, J.X., and R.E. Kasperson. 2001a. *Global environmental risk*. Tokyo and London: United Nations University Press and Earthscan.

Kasperson, R.E., and J.X. Kasperson. 2001b. *Climate change, vulnerability, and social justice*. Stockholm: Risk and Vulnerability Programme; Stockholm Environment Institute.

Kattsov, V., and E. Kallen. 2005. Future climate change: modelling and scenarios for the Arctic. In: Symon, C. (editor). *Arctic climate impact assessment (ACIA) scientific report*. Cambridge: Cambridge University Press: 99–150.

Kattsov, V., J. Walsh, W. Chapman, V. Govorkova, T. Pavolova, and X. Zhang. 2007. Simulation and projection of Arctic freshwater budget components by the IPCC AR4 global climate models. *Journal of Hydrometeorology* 8: 571–589.

Keskitalo, E.C.H. 2008a. *Climate change and globalization in the Arctic: an integrated approach to vulnerability assessment*. London: Earthscan.

Keskitalo, E.C.H. 2008b. Vulnerability and adaptive capacity in forestry in northern Europe: a Swedish case study. *Climatic Change* 87(1–2): 219–234.

Klein, R., S. Eriksen, L. Naess, A. Hammill, T. Tanner, C. Robledo, and K. O'Brien. 2007. Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance. *Climatic Change* 84(1): 23–44.

Klein, R., E.L. Schipper, and S. Dessai. 2005. Integrating mitigation and adaptation into climate and development policy: three research questions. *Environmental Science and Policy* 8(6): 579–588.

Kral, M. 2003. *Unikkaartuit: meanings of well-being, sadness, suicide, and change in two Inuit communities*. Ottawa: Health Canada, National Health Research and Development Programs.

Krupnik, I., and D. Jolly (editors). 2002. *The Earth is faster now: indigenous observations of arctic climate change*. Fairbanks, Alaska: Arctic Research Consortium of the United States.

Laidre, K.L., I. Stirling, L.F. Lowry, Ø. Wiig, M.P. Heide-Jørgensen, and S.H. Ferguson. 2008. Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. *Ecological Applications* 18(sp2): S97–S125.

Laidler, G.J., and P. Elee. 2008. Human geographies of sea ice: freeze/thaw processes around Cape Dorset, Nunavut, Canada. *Polar Record* 44(228): 51–76.

Laidler, G.J., and T. Ikummaq. 2008. Human geographies of sea ice: freeze/thaw processes around Igloolik, Nunavut, Canada. *Polar Record* 44(229): 127–153.

Lemmen, D., F. Warren, J. Lacroix, and E. Bush. 2008. *From impacts to adaptation: Canada in a changing climate 2007*. Ottawa, ON: Government of Canada.

L'Heureux, M., M. Mann, B. Cook, B. Gleason, and R. Vose. 2004. Atmospheric Circulation Influences on Seasonal Precipitation Patterns in Alaska During the Latter 20th Century. *Journal of Geophysical Research* 109 (D6): D06106.

Loeng, H. 2005. Marine systems. In: Symon, C. (editor). *Arctic climate impact assessment (ACIA) scientific report*. Cambridge: Cambridge University Press: 454–538.

Manson, G., and S. Solomon. 2007. Past and future forcing of Beaufort Sea coastal change. *Atmosphere-Ocean* 45(2): 107–122.

Martello, M. 2008. Arctic indigenous peoples as representations and representatives of climate change. *Social Studies of Science* 38(3): 351–376.

McBean, G. 2005. Arctic climate: past and present. In: Symon, C. (editor). *Arctic climate impact assessment (ACIA) scientific report*. Cambridge: Cambridge University Press: 22–60.

McCarthy, J., O. Canziani, N. Leary, D. Dokken, and K. White. 2001. *Climate change 2001: impacts, adaptation, and vulnerability*. Cambridge: Cambridge University Press (Contribution of working group II to the third assessment report of the Intergovernmental Panel on Climate Change).

McCarthy, J., and M. Martello. 2005. Climate change in the context of multiple stressors and resilience. In: Symon, C. (editor). *Arctic climate impact assessment (ACIA) scientific report*. Cambridge: Cambridge University Press: 945–988.

McLeman, R., and B. Smit. 2006. Migration as a human adaptation to climate change. *Climatic Change* 76(1–2): 31–53.

Nickels, S., C. Furgal, M. Buell, and H. Moquin. 2006. *Unikkaaqatigiit–putting the human face on climate change: perspectives from Inuit in Canada*. Ottawa: Inuit Tapiriit Kanatami; Nasivvik Centre for Inuit Health and Changing Environments at Universite Laval; Ajunnginiq Centre, National Aboriginal Health Organization.

Nishi, J., and L. Buckland. 2000. *An aerial survey of Caribou on western Victoria Island*. Yellowknife: Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development.

Noongwook, G., The native village of Savoonga, The native village of Gambell, H.P. Huntington, and J.C George. 2007. Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. *Arctic* 60(1): 47–54.

NWT housing representative. 2009. Personal communication. Ulukhaktok, 6 March 2009.

NWT housing. 2006. Public housing program. Yellowknife: NWT housing. URL: http://nwthc.gov.nt.ca.

NWT statistics. 2006. *Selected socio-economic indicators, Northwest Territories*. Yellowknife: Northwest Territories Bureau of Statistics (2006 community indicators).

NWT wildlife. 2007. NWT Peary caribou/NWT Dolphin-Union caribou. Yellowknife: NWT wildlife URL: http://www.nwtwildlife.com/Publications/speciesatriskweb/pearycaribou.htm.

Oakes, J., and R. Riewe. 1997. *Culture, economy, and ecology: case studies from the circumpolar region*. Millbrook, ON: The Cider Press.

O'Brien, K., L. Sygna, and J. Haugen. 2004. Vulnerable or resilient? A multi-scale assessment of climate impacts and vulnerability in Norway. *Climatic Change* 64(1): 193–225.

Parkins, J., and N. MacKendrick. 2007. Assessing community vulnerability: a study of the mountain pine beetle outbreak in British Columbia, Canada. *Global Environmental Change* 17: 460–471.

Pearce, T., J. Ford, G. Laidler, B. Smit, F. Duerden, M. Allarut, M. Andrachuk, S. Baryluk, A. Dialla, P. Elee,

A. Goose, T. Ikummaq, E. Joamie, F. Kataoyak, E. Loring, S. Meakin, S. Nickels, K. Shappa, J. Shirley, and J. Wandel. 2009. Community collaboration and climate change research in the Canadian Arctic. *Polar Research* 28(1): 10–27.

Pouliotte, J., N. Islam, B. Smit, and S. Islam. 2006. Livelihoods in rural Bangladesh. *Tiempo* 59: 18–22.

Pratley, E. 2005. Changing livelihoods/changing diets: the implications of changes in diet for food security in Arctic Bay, Nunavut. University of Guelph, Department of Geography.

Riedlinger, D. 2001. Responding to climate change in northern communities: impacts and adaptations. *Arctic* 54(1): 96–98.

Riedlinger, D., and F. Berkes. 2001. Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. *Polar Record* 37(203): 315–328.

Rigor, I., R. Colony, and S. Martin. 2000. Variations in surface air temperature observations in the Arctic, 1979–97. *Journal of Climate* 13: 896–914.

Russell, D. 2007. Population size of Peary caribou in Canadian Arctic islands. In: Armstrong, R.L., and M.J. Brodzik (editors). *Global outlook for ice and snow*. Nairobi: United Nations Environment Programme.

Sakakibara, C. 2008. 'Our home is drowning': Inupiat storytelling and climate change in Point Hope, Alaska. *The Geographical Review* 98(4): 456–475.

Schroter, D., C. Polsky, and A. Patt. 2005. Assessing vulnerabilities to the effects of global climate change: an eight step approach. *Mitigation and Adaptation Strategies for Global Change* 10: 573–596.

Smit, B., I. Burton, R. Klein, and J. Wandel. 2000. An anatomy of adaptation to climate change and variability. *Climatic Change* 45: 223–251.

Smit, B., and M. Skinner. 2002. Adaptation options in agriculture to climate change: a typology. *Mitigation and Adaptation Strategies for Global Change* 7: 85–114.

Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16 (3): 282–292.

Smith, D. 1998. Recent increase in the length of the melt season of perennial Arctic sea ice. *Geophysical Research Letters* 25(5): 655–658.

Smith, T., and L. Harwood. 2001. Observations of neonate ringed seals, *Phoca hispida*, after early break-up of the sea ice in Prince Albert Sound, Northwest Territories, Canada, Spring 1998. *Polar Biology* 24: 215–219.

Smithers, J., and B. Smit. 1997. Human adaptation to climatic variability and change. *Global Environmental Change* 7(2): 129–146.

Stern, P. 2001. Modernity at work: wage labor, unemployment, and the moral economy of work in a Canadian Inuit community. University of California, Berkeley, Department of Anthropology.

Stirling, I., N. Lunn, and J. Iacozza. 1999. Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climate change. *Arctic* 52(3): 294–307.

Stirling, I., and C. Parkinson. 2006. Possible effects of climate warming on selected populations of polar bears (*Ursus Maritimus*) in the Canadian Arctic. *Arctic* 59(3): 261–275.

Stirling, I., and T.G. Smith. 2004. Implications of warm temperatures and an unusual rain event for the survival of ringed seals on the coast of southeastern Baffin Island. *Arctic* 57(1): 59–67.

Stroeve, J., M. Holland, W. Meier, T. Scambos, and M. Serreze. 2007. Arctic sea ice decline: faster than forecast. *Geophysical Research Letters* 34: L09501.

Sutherland, K., B. Smit, V. Wulf, and T. Nakalevu. 2005. Vulnerability in Samoa. *Tiempo* 54: 11–15.

Takano, T. 2005. Connections with the land: land-skills courses in Igloolik, Nunavut. *Enthnography* 6(4): 463–486.

Tremblay, M., C. Furgal, V. Lafortune, C. Larrivee, J. Savard, M. Barrett, T. Annanack, N. Enish, P. Tookalook, and B. Etidloie. 2006. Communities and ice: linking traditional and scientific knowledge. In: Riewe, R., and J. Oakes (editors). *Climate change: linking traditional and scientific knowledge*. Winnipeg and Quebec City: University of Manitoba Aboriginal Issues Press and ArcticNet: 123–138.

Tschakert, P. 2007. Views from the vulnerable: understanding climatic and other stressors in the Sahel. *Global Environmental Change* 17: 381–396.

Turner, B., R.E. Kasperson, P. Matson, J. McCarthy, R. Corell, L. Christensen, N. Eckley, J.X. Kasperson, A. Luers, M. Martello, C. Polsky, A. Pulsipher, and A. Schiller. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences* 100(14): 8074–8079.

Tyler, N., J. Turi, M. Sundest, S.K. Bull, M. Sara, E. Reinert, N. Oskal, C. Nellemann, J. McCarthy, S. Mathiesen, M. Martello, O. Magga, G. Hovelsrud, I. Hanssen-Bauer, N. Eira, I. Eira, and R. Corell. 2007. Saami reindeer pastoralism under climate change: applying a generalized framework for vulnerability studies to a sub-Arctic social-ecological system. *Global Environmental Change* 17: 191–206.

UNFCCC (United Nations framework convention on climate change). 2002. United Nations framework convention on climate change. Switzerland: United Nations Environment Programme/World Meteorological Organization Information Unit on Climate Change (IUCC) on behalf of the Interim Secretariat of the Convention.

Wall, E., and K. Marzall. 2006. Adaptive capacity for climate change in Canadian rural communities. *Local Environment* 11(4): 373–397.

Walsh, J. 2005. Cryosphere and hydrology. In: Symon, C. (editor). *Arctic climate impact assessment (ACIA) scientific report*. Cambridge: Cambridge University Press: 183–242.

Wein, E., M. Freeman, and J. Makus. 1996. Use of and preference for traditional foods among the Belcher Island Inuit. *Arctic* 49(3): 256–264.

Wenzel, G. 1991. *Animal rights, human rights*. Toronto: University of Toronto Press.

Wenzel, G. 1995. Ningiqtuq: resource sharing and generalized reciprocity in Clyde River, Nunavut. *Arctic Anthropology* 32: 43–46.

Wesche, S., and D. Armitage. 2006. Adapting to environmental change in a northern delta system. In: Riewe, R., and J. Oakes (editors). *Climate change: linking traditional and scientific knowledge*. Winnipeg and Quebec City: University of Manitoba Aboriginal Issues Press and ArcticNet: 105–120.

Wolfe, B., D. Armitage, S. Wesche, B. Brock, M. Sokal, K. Clogg-Wright, C. Mongeon, M. Adam, R. Hall, and T. Edwards. 2007. From isotopes to TK interviews:

towards interdisciplinary research in Fort Resolution and the Slave River delta, Northwest Territories. *Arctic* 60(1): 75–87.

Yohe, G., and R. Tol. 2002. Indicators for social and economic coping capacity – moving toward a working definition of adaptive capacity. *Global Environmental Change* 12(1): 25–40.

Zhang, X., and J. Walsh. 2006. Toward a seasonally ice-covered Arctic Ocean: scenarios from the IPCC Ar4 model simulations. *Journal of Climate* 19: 1730–1747.

Zhang, Y., W. Chen, and D. Riseborough. 2006. Temporal and spatial changes of permafrost in Canada since the end of the Little Ice Age. *Journal of Geophysical Research* 111: D22103.