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# Climate Change and Hazards Associated with Ice Use in Northern Canada

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## Abstract

Research conducted with the communities of Igloolik, Ulukhaktok, and Churchill in northern Canada documents increasing exposure to hazards associated with ice use for hunting and travel. This trend is related to changing ice conditions. Instrumental records show later ice freeze-up and earlier breakup since the late 1970s, increasing temperatures, and changes in weather in the case study communities. Elders and mature community members, drawing upon their traditional knowledge, describe similar changes in ice and other climate-related conditions in recent years. These changes are increasing the risks of utilizing the ice for hunting and travel and they are reducing access to traditional food. Change in risk-taking behavior among users of the ice has also been documented in Igloolik and Ulukhaktok over the last few decades and has shaped the implications of more recent changes in ice conditions. Comparison between the communities reveals uneven consequences of changing ice conditions which is linked to the nature of ice use, local physiological setting, and community socio-cultural dynamics.

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## Introduction

> "Sea ice [I'm] constantly using it. If it wasn't for ice [I] probably wouldn't be where [I] am right now. It assists [me] in getting about, it assists [me] in hunting, [I] use all types of ice. Even in the summer, when [I] cannot get about on the landfast ice [I] still hunt on ice."
>
> Inuit elder *in* Laidler et al. (2008)

Communities in arctic and subarctic Canada are dependant on fresh and saltwater ice and the wildlife harvesting and transportation opportunities it provides (Nuttall et al., 2005). The acquisition and consumption of traditional foods provided by hunting is of great social, cultural, and economic importance to communities, bringing many nutritional benefits (Collings et al., 1998; Egeland et al., 2001; Chan et al., 2006). Hazards associated with ice use are well known and are an accepted part of life in the north. Oral histories recollect stories of hunters who drifted away on ice floes never to return, drowned after falling through thin ice, got lost in poor weather conditions, or starved when access to traditional food was constrained (Wilkinson, 1955; MacDonald, 1998). Ice-related hazards continue to claim lives, extract financial cost in terms of lost and damaged equipment, and stress traditional food systems.

It is widely noted among communities in northern Canada, and generally across the Arctic, that the climate is changing and increasing the hazardousness of using the ice (Huntington et al., 2005; Oakes and Riewe, 2006). Climate change, however, does not occur in isolation, affecting human activities through dynamic interactions with changing resource use and livelihood conditions (McLeman and Smit, 2005). In recent decades, for instance, new technology and changing community dynamics have affected how the ice is used (Henshaw, 2007). In combination with climate change, these trends are creating new hazard exposures, attenuating old ones, and exacerbating others.

This paper examines how and why exposure to hazards associated with ice use has changed in communities in northern Canada, focusing on ice conditions or events with the potential to cause harm to community members. It begins by reviewing the concept of hazard exposure and evaluates existing scholarship on hazards in northern Canada. Using examples from case studies in Nunavut, the Inuvialuit Settlement Region (ISR) in the Northwest Territories (NWT), and Manitoba, and drawing upon previously published research by the authors, the paper documents human use of the ice and identifies the nature of hazardous conditions. The paper then examines changes in hazard exposure associated with ice use, analyzing the role played by physical and non-physical processes, and examining differences and similarities between the case study communities.


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## The Concept of Hazard Exposure

A natural hazard is a naturally occurring event with the potential to cause harm to man; without humans, hazards become natural events and thus, from a human viewpoint, become irrelevant (Haque and Etkin, 2007). Hazard exposure refers to the sensitivity of people and communities to conditions that represent hazards, reflecting actual or potential for loss of life, physical injury, psychological harm, and damage. The majority of hazards research in general and northern Canada in particular when characterizing hazard exposure and assessing change over time has focused on the nature of, and change in, physical conditions themselves in terms of their magnitude, frequency, and spatial distribution (Ford and Smit, 2004). This is reflected in the largely technological- and engineering-based responses that have been proposed to mitigate hazard impact, aimed at controlling and/or modifying physical conditions and processes (for Arctic examples see Andre'eva et al., 1995; Wolfe et al., 1998; Seligman, 2000; Nelson et al., 2002; Johnson et al., 2003; Instanes et al., 2005).

Notwithstanding the physical focus of hazards research, the last few decades have witnessed the emergence of new perspectives focusing on the social construction of hazards. In this respect, the work of Sen (1981) and Hewitt (1983) was seminal. Challenging the view that hazards are largely a function of physical processes, they argued that hazard exposure is as much dependent upon structures of society, access to resources, culture, and human capital as it is on physical processes. Focusing on the role of everyday social forces and larger historical conditions in exposing populations to hazardous conditions, this work charted new ground and was further developed by work in political economy and political ecology (Blaikie and Brookfield, 1987; Alexander, 1991; Watts and Bohle, 1993; Blaikie et al., 1994). Research on the societal forces shaping exposure gained new impetus in the 1990s as the UN International Decade for Natural Disaster Reduction failed to stem the trend of increasing hazard loss despite remarkable technological achievements (Wisner et al., 2004). Despite these developments, as Haque and Etkin (2007) noted, in much of the hazard literature and in the public consciousness, hazard exposure is still viewed, analyzed, and treated as being determined by physical processes and events.

Research assessing the implications of climate change for hazard exposure initially adopted the physical focus common in the literature, modeling the implications of simulated temperature and precipitation change for the magnitude, frequency, and spatial distribution of hazardous conditions (Duerden, 2004). In northern regions too, the impacts of climate change have been approached largely from the physical domain (Maxwell, 1997; Anisimov and Fitzharris, 2001; Nelson et al., 2002). The Arctic Climate Impact Assessment (ACIA, 2005), for instance, while having chapters on indigenous perspectives and human vulnerability, focused largely on physical conditions. However, new research drawing upon concepts in vulnerability science is beginning to conceptualize the complexities of human-environment interactions that shape hazard exposure in a changing climate. This is reflected in the Fourth Assessment Report of The Intergovernmental Panel on Climate Change (IPCC, 2007) and in recent publications (Turner et al., 2003; Ford and Smit, 2004; O'Brien et al., 2004; Smit and Wandel, 2006; Ford et al., 2008; Ford, in press). Hazard exposure, as conceptualized in this paper, draws upon this literature, treating exposure as being determined by characteristics of physical conditions *and* the nature of the human system. The characteristics of physical conditions include magnitude, frequency, spatial dispersion, duration, speed of onset, timing, and temporal spacing of physical conditions to which human systems are sensitive. The nature of the human system that relates to hazard exposure concerns the location and structure of communities relative to the physical risks, and is also strongly linked to livelihood conditions and strategies.

In this conceptualization exposure is dynamic, changing as characteristics of the human system change relative to the physical conditions, and changing as the physical stimuli themselves change relative to human occurrence and livelihoods (Smit and Pilifosova, 2003; Ford et al., 2006b). It also reflects human and physical conditions and processes operating at broader scales, which elsewhere are called "root causes" (Blaikie et al., 1994) or "influences acting on place" (McCarthy and Martello, 2005), or even "drivers" and "determinants" (Smit and Wandel, 2006). In a northern Canadian context, for example, social and economic change have filtered through the particular attributes of groups or individuals to influence decisions such as where to hunt, what to hunt, when, and what equipment is taken along (Ford et al., 2006b). This can increase or decrease sensitivity to physical conditions depending on the nature of the change. Climate change interacts to affect the characteristics of physical conditions that affect people, changing the nature of the potential risks posed.

## Community Case Studies

Case studies situated in particular places and cultures are important to understand the dynamic interaction between human and physical processes shaping hazard exposure (Ford and Smit, 2004). To analyze how and why exposure to hazards associated with ice use has changed over time in northern communities, projects were developed with three communities that depend upon use of the ice for hunting and travel: Igloolik, Nunavut; Ulukhaktok, Northwest Territories (NWT); and Churchill, Manitoba (Fig. 1).

Igloolik is a coastal community of 1538 people (95% Inuit) located on Igloolik Island in northern Foxe Basin, Nunavut, approximately 320 km north of the Arctic Circle. Located off the east coast of Melville Peninsula, the island and the mainland have a relatively flat topography, can be classified as having a polar tundra climate, and are located in the northern Arctic ecozone. Sea ice dominates the surrounding waters for much of the year. Breakup of the sea ice occurs in late July or early August and freeze-up occurs in late October, with a brief open water season between these dates.

Ulukhaktok, formerly Holman, is a coastal community of 434 people (95% Inuvialuit) located on the west coast of Victoria Island in the Inuvialuit Settlement Region (ISR), NWT. Occupying the northern Arctic ecozone and with a polar tundra climate, the geography of Victoria Island is diverse, characterized by lowlands in the east that gradually rise from the coast to form undulating hills and rugged plateaus in the west. Freeze-up generally occurs between the end of October and mid November, and breakup usually occurs in late June or early July.

Churchill is located on the coast of Hudson Bay at the mouth of the Churchill River in northern Manitoba within the Hudson Plains ecozone. The community is located in the subarctic climate zone and is approximately 840 km south of the Arctic Circle. Churchill has a population of 923 people, 485 of which are Aboriginal peoples from among Inuit, Cree, Dene/Chipewyan or other Native groups, including Métis and mixed Aboriginal background. The ice in the Churchill region is the last to breakup in Hudson Bay, generally occurring in mid-July with freeze-up occurring in late November.

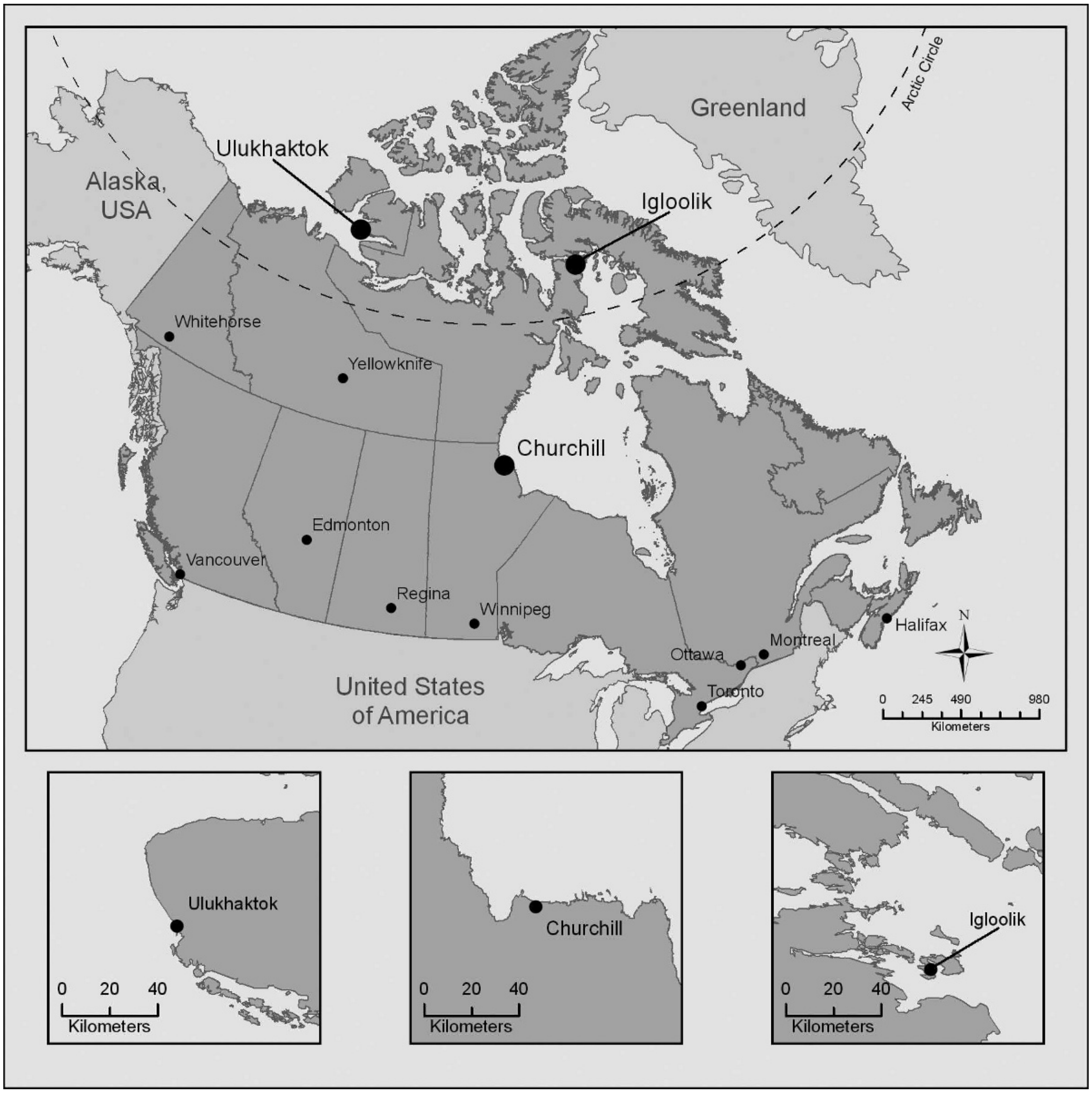


**FIGURE 1. Map of case study communities.**

Igloolik and Ulukhaktok share a similar history. Both communities have expanded rapidly since the 1960s, when groups of semi-nomadic Inuit, encouraged by the provision of housing, health, and education facilities by the federal government, settled in their locations (Damas, 2002). Despite undergoing rapid social, economic, and political changes in the past half-century, community members in both settlements continue to live in close association with the natural environment, and harvesting fish and wildlife remains important in the lives of most community members both economically and for subsistence (Usher, 2002; HIS, 2003). Churchill has a longer history as a permanent settlement, originally established by the Hudson's Bay Company in 1717. The community changed rapidly in the 1930s with the completion of a Hudson Bay railroad and development of a deepwater port for shipping grain. Since the 1930s the economy of Churchill shifted from depending on the sale of furs to a more diverse economic base including transportation, mining, forestry, commercial fishing, and more recently tourism. Nevertheless, harvesting remains an important activity in the livelihoods of many community members.

Socioeconomic-demographic differences between Churchill and the other two communities are also evident; 56% of Igloolik residents and 64% of Ulukhaktok residents participate in the wage economy compared to 84% of Churchill residents (Statistics Canada, 2001). Average earnings are correspondingly lower in Igloolik (Canadian $20,156) and Ulukhaktok (Canadian $19,385), compared to Churchill (Canadian $28,951) (Statistics Canada, 2001). The population of the two Inuit communities is also younger, with 76% of Igloolik residents and 64% of Ulukhaktok under the age of 34 in the 2006 census compared to 52% of Churchill residents (Statistics Canada, 2001).

### *COMMUNITY SELECTION*

The three case study communities, forming a transect from the western Arctic to the eastern subarctic, were chosen to be reflective of the diverse culture and dynamics of communities along Canada's northern coastline and the different climatic, ecological, and physiographic contexts which they occupy. This permitted an evaluation of the similarities and differences between situations in contrasting sociophysical settings. Selection also reflected research history in these communities. As part of the ArcticNet project (ArcticNet brings together scientists and partners in Inuit organizations, northern communities, federal and provincial agencies, and the private sector to study the impacts of climate change in the coastal Canadian Arctic. See http://www.arcticnet-ulaval.ca/.), all authors have ongoing research projects using a broadly consistent approach to investigate the conditions which communities have experienced and characterize community vulnerability to climate change. The research presented in this paper is a product of this collaboration, drawing together insights from traditional knowledge and social and physical science to better understand changing exposure to ice hazards in northern Canada.

## Data Collection

Multiple methods were used to: identify ice conditions that represent hazard exposures, provide insights into how they have changed over time, and identify determinants of hazard exposure. A community-based approach guided the research process, including the establishment of a cooperative research venture with the communities in question, meaningful involvement of participants at all stages of the research (i.e. design, data collection, verification, and evaluation), and the employment and training of local researchers. Two local research assistants were employed in each community (three in Ulukhaktok) and were selected based on their long-term residence in the respective communities, familiarity with local culture and hunting practices, and expertise of working with researchers and community members.

### *SEMI-STRUCTURED INTERVIEWS*

A total of 115 semi-structured interviews were carried out within a broad range of age and socioeconomic groups, including full-time hunters, those with full- or part-time waged employment, the unemployed, and elders. The semi-structured interviews were guided by an open-ended interview guide that identified key themes to be covered. This allowed interviewees to concentrate on ice exposures they considered important rather than predetermined ones. Framing the interviews in this manner permitted greater understanding of the complex web of factors operating at different spatial temporal scales that shape hazard exposure.

Interviewees were selected to obtain a representation of all sectors of the adult population in the community and were remunerated according to local guidelines. Research subgroups were identified in collaboration with local researchers. To make possible the description of change over time and identification of ice hazards, extra weighting was given to the selection of mature community members and those actively using the ice. The sample selection was obtained by a ''snowball'' sampling method whereby community assistants identified people within groups willing to take part, who in turn suggested others who might be willing to be involved. In Igloolik and Ulukhaktok, interviews were conducted in English and the Inuit language (Inuktitut in Igloolik, and Inuvialuktun and Innuinaqtun in Ulukhaktok), with local collaborators providing translation and guidance. In Churchill, interviews were setup with the help of a community liaison and the interviews were conducted by the researcher in English.

### *PARTICIPANT OBSERVATION*

Participant observation refers to the process of experiential learning that occurs during fieldwork as a function of ''being there'' and engaging in daily life and social relationships, thus providing contextual understanding of cultural realties (Roncoli, 2007). Application of this method in the three communities ranged from walking around communities with an elder or experienced hunter, to participating in hunting and fishing trips to observe and experience concepts discussed in interviews, to experiencing and observing community life.

Experiencing and participating in community routines and practices enabled the development of a better understanding and contextualization of local perspectives of hazard exposure obtained in the interviews, allowing questions to be asked in context, and allowing elders, hunters, and others to discuss their observations and opinions ''on-site.'' The use of participant observation techniques allowed findings from the interviews to be compared with personal observations to evaluate consistency in response and to assess congruency with observations of daily life. Participant observation also promoted the establishment of interpersonal relationships and enhanced knowledge-sharing.

### *SECONDARY SOURCES*

Information on hazard exposures associated with ice use, their determinants, and how they have changed over time was also derived from analysis of secondary sources. Secondary sources were also used to assess consistency in insights between the interviews and participant observation with other accounts. A variety of sources were used in this project including government reports, ice records, the Igloolik Oral History Project, and the Inuvialuit Harvest Study. Instrumental data on changes in the nature of physical conditions that pose risks were obtained from the published literature and from ongoing research in which the authors are involved.

### *IMPLICATIONS OF DATA COLLECTION STRATEGY*

The methodology used in this research attempted to provide a venue for community members to identify hazard exposures associated with ice use, how they have changed over time, and why. Various filters and biases, however, shape the collection and interpretation of the data.

Gendered assumptions are likely to affect the data obtained. While females were well represented in the sample, and one of the local assistants was female (in Ulukhaktok), the work largely focuses on risks associated with hunting and traveling on the ice, and is therefore strongly indicative of the experiences and realities of males involved in the harvesting sector. The provision of payment and/or small gift as part of the research strategy encouraged participation in the research. This is standard practice when working with northern communities and is essentially required to ensure reasonable representation across age and gender. Payment, however, can affect the participation of certain groups and create a situation where interviewees provide answers that they think the interviewer wants to hear. Additionally, in Igloolik and Ulukhaktok, the translation of interviews has the potential to influence the nature of the data obtained, with the interpreter acting as a lens onto what is translated. This in turn leads to a greater concern when interpreting interviews of how well the researcher understands the experiences conveyed in the interview and how researchers identify and communicate salient points.

A number of strategies were utilized to manage these potential biases. Bias was minimized through the use of open-ended interviews, whereby interviewers avoided asking questions on topics they believed to be important, allowing interviewees to concentrate on changes and hazards they considered pertinent.

Transcripts of interviews were reviewed with local research assistants to assess accuracy and completeness. The research findings were reviewed with community members thus providing a check on the extent to which the researchers captured community understanding of change in ice exposures and key drivers of change. The use of multiple translations, and the cross referencing of narratives obtained in the interviews with participant observation and secondary sources enabled the information obtained to be checked to assess consistency and credibility in the findings. Throughout the paper, extensive quotes from the interviews are also used to present residents' perspectives of ice hazards and change over time. Although the quotes were selected by the authors, they highlight how the interview narratives were drawn upon in the analysis.

### *NOTES ON COMPARATIVE ANALYSIS*

The three case studies described in this paper share a broadly consistent approach to understanding changing hazard exposure. However, differences in data collection and interpretation are inevitable when the results from three separate projects are brought together *post hoc*. Further, the Igloolik work presented here draws upon over 5 years of research and synthesizes findings from an extensive history of research in the community to support key arguments. This compares to the Ulukhaktok study which has been underway for 3 years and Churchill 2 years, and for which comparably less scholarly work on human-environment interactions was available to support key arguments. Despite these differences, we believe the three studies share significant similarities, and the benefits of conducting a comparative analysis outweigh the drawbacks.

Another way to do comparative research is for all case studies to use the same approach from the beginning and for regular comparison of research progress and findings as the studies progress. This was beyond the scope of the work presented here and requires a major collaborative effort to be established prior to conducting the research. As part of the International Polar Year, however, researchers in the Community Adaptation and Vulnerability in Arctic Regions (CAVIAR) project will utilize a consistent theoretical and methodological approach to compare climate change vulnerability and its drivers across the circumpolar north. (CAVIAR is an international consortium of partners from the eight Arctic nations. Led by the University of Guelph in Canada and CICERO in Norway, the main goal of CAVIAR is to identify and characterize climate change vulnerability and important drivers across the Arctic.)

## Hazards Associated With Ice Use

### *IGLOOLIK*

Igloolik is located on a small island (103 km$^2$) and once the ocean starts to freeze community members are essentially stuck until the ice reaches a thickness capable of supporting the weight of a snowmobile. With limited hunting opportunities on Igloolik Island, people often take risks trying to hunt seals at ice leads, access caribou hunting grounds on the mainland, and travel to the community of Hall Beach (100 km to the south) before the ice is fit for use. Participants indicated that the majority of accidents occur at this time and are associated with people falling through thin slushy ice that is often hidden by snow (see Table 1). The moving pack ice walrus hunt in winter is widely considered the most dangerous harvesting activity in Igloolik. Conducted only by experienced and mature hunters on ice that is constantly in motion, driven by wind and ocean currents, hunters are exposed to the potential to be caught on ice that drifts out to open water. Interviewees indicated sea ice breakup to be the least dangerous time in Igloolik despite it being the time of most widespread use by the majority of community members. Limited time is spent travelling on the ice at this time of the year with seals hunted close to the community on ice leads.

### *ULUKHAKTOK*

The landscape to the northwest of Ulukhaktok is rugged and difficult to travel on; therefore, community members travel on the sea ice to access terrestrial caribou and muskox harvesting grounds otherwise difficult to access via the land. The ice is also widely used in fall for hunting seals. This exposes hunters to similar risks faced by Igloolik Inuit, including thin and snow-covered ice (see Table 1). The coldest months of the year (December–March) are considered by community members to be the safest for travel due to the thickness and stability of the ice. During the winter mostly experienced hunters use the sea ice to hunt seals, trap foxes, access muskox harvesting areas, and travel to neighboring communities. Rough ice, cracks, open water leads, and storm events pose hazards in winter although accidents are uncommon at this time. The most common time to travel on the sea ice is during the spring (March–June) when temperatures become warmer and the daylight is returning. A popular harvesting activity for the entire community is the king eider duck harvest in May and June. Community members travel on the sea ice to access duck hunting grounds (difficult or inaccessible by land), an activity that depends on stable sea ice conditions. The timing of sea ice breakup is variable, and harvesters often take risks to travel on the ice even when it is melting and thin to access duck harvesting areas.

### *CHURCHILL*

In Churchill interviewees described spring as being particularly hazardous for ice travel. Spring hunting grounds near Churchill are largely located to the north and require travel over the Churchill River estuary at a time when warming temperatures, longer hours of sunlight, and estuarine flooding degrade the sea ice (see Table 1 and Fig. 2). In mid-to-late spring, smooth ice has often melted to a slushy composition which has the potential to damage snowmobiles and hide dangerous patches of thin ice. Fall is also a potentially dangerous time for ice use in Churchill. Risks are similar to those encountered in Igloolik and Ulukhaktok, including difficulty in reading ice conditions such as thickness and continuity. Other hazards span winter, fall, and spring, including the danger of being caught on ice that is blown out to open water by a south wind. While there have been few incidents where this has occurred, local hunters are aware of the risks. Large cracks in the ice are a problem encountered throughout the ice season; a problem mentioned in Igloolik and Ulukhaktok. Flooding also occurs on the ice year-round caused by tides and increased water levels of rivers carrying water from areas south of Churchill, and is a problem that does not occur in the other communities. Flooding results in people having to take detours to access hunting areas and creates slush and thin ice which poses dangers to ice travel.

## Changing Hazard Exposure

Elders and mature community members in the three communities consistently identified a trend of changing hazard

**TABLE 1**

**Selected hazards associated with use of the ice.**

| Hazardous condition | Date and location | Notes |
|---|---|---|
| Ice break-up | March 2005, Ulukhaktok | Polar bear hunters became separated from dogs and the polar bear when the ice flow broke up. Two dogs were not recovered. |
| Thin ice | November 2006, Igloolik | Loss of snowmobiles through thin ice. No fatalities, snowmobile was lost. |
| | May 2006, Ulukhaktok | One snowmobile fell through thin ice. No fatalities, snowmobile was recovered. |
| Ice cracks | December 2003, Igloolik | Two fatalities as snowmobiles fell into open water on way to Hall Beach. One survivor. |
| | February 2007, Ulukhaktok | One snowmobile driven by a father and son checking their fox trap-line fell into a large crack in the sea ice. No injuries, snowmobile was recovered |
| Wind | August 2005, Ulukhaktok | Two power boats with caribou hunters were stranded in Prince Albert Sound because a sudden shift in wind direction pushed broken ice into the mouth of the sound, blocking the travel route back to the community. |
| Flooding | April 2005, Churchill | One truck and one snowmobile became stuck in unexpected flooding on the Churchill River estuary. No fatalities, truck and snowmobile recovered, but snowmobile required extensive repairs. |
| | April 2005, Churchill | Three snowmobiles returning to town encountered a creek that had broken up and was several feet deep. One snowmobile crossed the open water then proceeded to pull the remaining snowmobiles and equipment across the creek. No fatalities, no damage to equipment. |

exposure over the last decade, in terms of experience with and potential for loss of life, physical and psychological injury, and damage. The dynamic interplay of physical and human factors shaping hazard exposure and their variation over space and time is addressed in this section. This section also identifies indicators which can be used to identify and monitor changes in social and physical drivers of hazard exposure.

*PHYSICAL CONDITIONS*

It is widely believed among users of the ice in the three communities that ice and associated climatic conditions have been changing beyond expected natural fluctuations and variability (Table 2). As noted locally, these changes have altered and tended to increase exposure to ice hazards. It is possible that changing livelihoods have altered the perception of the physical environment, with reported increasing exposure reflecting change in the observation and experience of risk. For example, elders noted how judging changes in temperature over time was difficult as they spend less time on the land nowadays. Similarly, changing hunting behavior may have brought hunters into greater contact with certain risks which are then perceived to be increasing in prevalence. However, many interviewees were cognizant of this and noted, taking into account potential altered perceptions, that physical conditions were nonetheless changing and increasing risk. This is one reason why multiple interviews were used in the research with the aim of obtaining different observations, experiences, and perceptions of change. Data from instrumental records, where available, were also used to complement local descriptions of change and are largely consistent with community identified trends.

**FIGURE 2. While returning from a hunting/fishing cabin at Button Bay west of Churchill in April 2005, a truck became stuck in unexpected flooding on the Churchill River estuary, an increasing occurrence in recent years (photo courtesy of P. Fitzpatrick).**

*Weather, Wind, and Ice*

Regarding the ability to use the ice safely, one of the concerns most frequently highlighted by participants in the three communities relates to the challenges posed by changing wind and weather patterns to traditional knowledge and understanding of the ice. With the visual clues of the weather becoming more difficult to read, identifying precursors of hazardous ice conditions is increasingly difficult. Typically, before going out on the land, hunters and users of the ice will look at the clouds' height, form, and the brightness and movement of stars, wind, as well as other environmental conditions, to attempt to forecast the weather in order to decide if it is safe to travel on the ice. Many users of the ice also rely on weather forecasts provided on the radio or television to supplement their own forecasts. Prediction is essential as the ability to anticipate and respond to dangers, opportunities, and changes is important for safe travel. Elders and experienced hunters noted that the weather was fairly predicable over the past several generations. In recent years, however, sudden and unexpected changes have become increasingly the norm in all seasons and have reduced the reliability of predictions.

"The foundation of the wind has changed, it's gone. The wind will now come from any direction, any time of the day. Before you could

TABLE 2

**Changes in climatic conditions observed by community members in Igloolik (I), Churchill (C), and Ulukhaktok (U).**

| Aspect of change | Reported change |
|---|---|
| Ice | • Later freeze-up, earlier break-up (I, C, U) |
| | • Less stable: breaks up suddenly (I, C, U) |
| | • Thinner in places (I, C, U) |
| | • Takes longer to reach thickness capable of supporting weight of snowmobile (I, C, U) |
| Wind | • More unpredictable (I, C, U) |
| | • Stronger wind (I, C, U) |
| | • Change in the predominant wind direction affecting the shape of snowdrifts (I, C) |
| Weather | • Increasing unpredictability: predictions never correct anymore (I, C, U) |
| | • More extremes of temperature (I, C, U) |
| Rainfall | • Occasional rainfall in winter months (C) |
| | • More precipitation as rainfall in spring (I) |
| Snow | • More snow on the ice if fall (I) |
| | • More powdery snow on the mainland during early fall (I) |
| | • More blizzards (I, U) |
| | • Fewer blizzards (C) |

predict [the wind] but not any more: [the wind will be from the south] and then in the same day the wind shifts direction.''

David Aqiaruq, Igloolik, 2006

''The weather nowadays is unpredictable. You can check the five day forecast but that doesn't mean that's the weather you're going to get.''

G. Lundie, Churchill, 2006

''When you are out camping, you can't be out—your tent will blow over, it [wind] comes up suddenly, it affects people out on the land… It is already affecting us and it will affect the people coming behind us.''

Anonymous, Ulukhaktok, 2005

In Igloolik, the increasing unpredictability and variability of the wind is a major concern to those who hunt walrus on the moving pack ice in winter. Sudden changes in wind direction from the south/southwest to northwest have the potential to strand hunters on drifting ice. This has always posed problems to walrus hunters but the increasing unpredictability of the wind is challenging the ability to safely hunt walrus in winter, undermining traditional understandings of the wind. There have been incidences in recent years of hunters being stranded on drifting ice and although there have been no serious accidents, hunters noted the increased potential for loss of life and injury, and increasing stress associated with using the ice at this time.

Community members in Ulukhaktok have observed an increase in the occurrence and strength of east winds during the winter, whereas east winds were previously not experienced until the spring. This is increasing the risks of using the ice in winter: strong east winds have created premature open water leads in the sea ice, preventing travelers from reaching harvesting grounds and exposing travelers to serious hazards. Changing wind patterns have also created extremely rough ice and thin ice at other times of the year, contributing to increasing the dangers of ice use throughout the year.

In Churchill the unpredictability of the wind is predominantly a concern during spring. Many hunting cabins are located to the north of Churchill on the Hudson Bay coast, and access requires crossing the frozen Churchill River. Wind and warm weather can affect the stability of river ice, and the increasing unpredictability is making it difficult to gauge when the ice will break. Participants described going on day trips north of the river during what they considered were good conditions, but then returning later in the day to find winds had broken up the ice and created surface flooding. While there have been no serious injuries or loss of equipment as a result of such events, there have been instances where people have become stuck crossing the river and have had to call for help.

Instrumental data sets capture trends described by community members. Hanesiak and Wang (2005), for example, detected a statistically significant trend of decreasing ''no-weather events'' (defined as no precipitation or visibility obscuration) in Churchill in the period 1952–2001. This trend is also evident in the data from Hall Beach, Nunavut, and Inuvik, NWT, communities which, due to close proximity, can be considered proxies for Igloolik and Ulukhaktok. Hanesiak and Wang (2005) attributed this to increased frequency of precipitation events. Zhang et al. (2004) likewise showed increased cyclonic activity in Arctic regions. These findings are consistent with community observations of more active weather, although additional analysis is needed to compare local meteorological data on wind direction, strength, and variability with local observations.

### *Ice Freeze-Up and Breakup Trends*

In all three communities ice freeze-up is occurring later in the year and breakup earlier in the year. Laidler et al. (2008), using data from Canadian Ice Service charts, reported a statistically significant (95%) trend of later freeze-up of approximately 0.6 days per year, or 1 week per decade between 1969 and 2005. The data set clearly indicates the concentration of anomalous ice conditions in recent years in the record: 1998 was the first year that freeze-up occurred in November (usually occurred in October), and since then freeze-up has occurred in November four times (2002, 2004, 2005, 2006). A notable shift towards earlier spring ice breakup is also apparent in the record (i.e. beginning in July instead of August), with a statistically significant trend (90%) of earlier ice breakup by 0.6 days per year for the years 1982–2005 (Laidler et al., 2008).

Annual sea-ice extent in the Beaufort Sea near Ulukhaktok has been decreasing for the period 1979–2000, and recent evidence suggests that sea ice extent continues to decline (Serreze et al., 2003; Barber and Hanesiak, 2004). Strong negative ice concentration anomalies have been identified in the fall and spring during sea ice freeze-up and breakup and correspond with overall increases in mean air temperature (+1 to +4°C) (Barber and Hanesiak, 2004). Trends in decreasing sea ice areal extent relate to late freeze-up (Berkes and Jolly, 2002) and early breakup events documented at locations near Ulukhaktok (Smith and Harwood, 2001).

At data points close to Churchill, trend analysis using data from the Canadian Ice Service indicates a statistically significant trend (at 99%) of later freeze-up of 0.26 days per year and earlier break up by 0.65 days per year over the period 1971–2003 (Gagnon and Gough, 2005). The breakup data are consistent with earlier work by Gough et al. (2004) which documents earlier ice breakup in southwest Hudson Bay of 5 days per decade from 1971 to 1999. More recent work by Stirling and Parkinson (2006) using passive microwave data demonstrates a similar trend: over the period 1978 to 2004 breakup in the Churchill region occurred on average 0.75 days per year earlier (99% significance level).

Trends captured in instrumental data sets are consistent with community descriptions of later freeze-up and earlier breakup.

"When I was younger I remember that the ice freezes at the end of September, or the first week of October … now it freezes [in] late October, even [the] first week of November."

H. Ittusardjuat, Igloolik, 2004

"Usually we get freezing ice by … October and this year [it] was late and it didn't start until the end of November; this has been happening for a few years."

Anonymous, Churchill, 2007

"[The timing of break-up] varies now, it's unpredictable … middle of June you can't even go far [be]cause you never know when the ice is going to leave now. Before that we used to be out round until the end of June and not be worried about the ice. Nowadays we can't even go far because we don't know when the ice is going to leave."

Anonymous, Ulukhaktok, 2005

Participants in the three communities also noted more that the ice is taking longer to reach a thickness capable of supporting travel, which combined with later freeze-up and altered wind patterns is contributing to thinner and non-uniform ice conditions which make ice travel more dangerous. Whereas the ice used to freeze within days under a consistent progression of thickness, now the ice tends to form, breakup/get blown out, then start forming again. This cycle goes on several times before the ice actually solidifies, which can lead to rougher ice conditions when it does form. According to participants, this process is compounded by increased temperature variability in fall, with freeze-up days of below 0°C followed by days of above freezing temperatures.

"What [I] have noticed … in the last five to eight years, [is that] when it should be freezing up … it becomes overcast, snow starts falling for a long period of time … that affects freeze-up … whenever it's overcast the temperature rises a bit, freeze-up doesn't occur as quickly …."

N. Arnatsiaq, Igloolik, 2004, quoted *in* Laidler et al. (2008)

"Long ago the cold gradually set-in and the ice gets thicker. Now [there are] long spells of strong winds and the ocean can't freeze-up."

M. Nigiyok, Ulukhaktok, 2005

For Igloolik, local observations correspond with instrumental data. Laidler et al. (2008) detected a statistically significant trend towards the ice taking longer to form once initial freezing has begun. During the 15 year period from 1982 to 1996, the time lag between 5/10 of the ocean being frozen and 9/10 was just less three days, but since 1996 this lag has increased to on average about nine days. Temperature data also shows a reduction in the day-to-day temperature variability for the daily minimum temperature. In the period 1977 to 2002, this variability decreased in a statistically significant fashion during the months of September and October (Laidler et al., 2008). This can result from the thermal mitigating effect of greater cloud cover, thus reducing nighttime temperature extremes. This in turn leads to slower ice formation as observed (Laidler et al., 2008).

Ice and temperature data for Churchill and Ulukhaktok have not been analyzed in this detail, but local observations are consistent with the increased frequency of weather events identified by Hanesiak and Wang (2005) (see above). They are also consistent with temperature data which demonstrate significant warming in fall and hence later and more gradual freeze-up similar to what has been documented in Igloolik. In Churchill, Gagnon and Gough (2005) similarly calculated a warming of 0.83°C and 1.25°C per decade between 1971 and 2001 in September and December, respectively, or 2.49°C and 3.75°C over the 30-year record. In Ulukhaktok local observations are consistent with documented warming trends in the Western Arctic where average annual temperature increased by 2°C within a 50-year period (1950–1998) (Lemmen and Warren, 2004).

As a consequence of these changes, and in combination with changes in the wind and weather described previously, ice travel is generally more dangerous across the seasons. Later and longer freeze-up is particularly problematic for Igloolik and Ulukhaktok residents on account of their dependence on the ice in fall to access hunting grounds and has enhanced the risk of sea ice travel. People express their unhappiness and impatience with delayed use of the ice, and have to purchase store food, with limited access to traditional foods (Ford, in press). Eagerness to use the ice when it is newly formed manifests itself in hunters taking risks, thus compounding the inherent dangers of ice use at this time. Coincident with changing ice conditions, there is widespread belief among community members that there has been an increase in accidents, with people falling through thin ice and damaging hunting equipment more often.

Churchill residents are generally less dependent on hunting than the other two communities and the later and longer freeze-up is not as much of a concern as people are more inclined to wait until the ice is suitable to use. In Churchill, changes in the dynamics of breakup on the Churchill River have had implications for the spring goose hunt. Hunters normally cross at the mouth of the river where the Churchill River meets the Hudson Bay to reach the goose hunting grounds to the north. However, changes in the breakup and thaw of the Hudson Bay and Churchill River estuary have affected harvest success, increasing the danger of crossing the ice. Some hunters are still crossing the river by snowmobile to participate in the spring goose hunt despite thinner ice conditions, increasing the potential for injury, loss of life, and damage to equipment.

"It used to be I would goose hunt at Seal River by snowmobile [at the end of May], one year I went June 2nd. In the last few years the first week of May was pushing it. It's more dangerous in the first week of May but that used to be prime time to sled!"

R. Daudet, Churchill, 2006

"Goose hunting across the river in spring is more dangerous. I still cross the river but if you're not experienced it's very dangerous. You have to be able to read the ice; it's the difference of making it home."

D. Lundie, Churchill, 2006

Earlier and more rapid breakup are also affecting Ulukhaktok. Duck harvesters are taking increased risks to travel on the melting sea ice by snowmobile and/or travel by boat through difficult ice conditions in order to continue to harvest ducks. There have been several incidences of people's snowmobiles falling through the melting ice causing injuries and damaging machines.

"We hunt ducks in the spring. You need good ice to hunt ducks, [to] go by 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, Ulukhaktok, 2005

Not all the changes in physical conditions are having negative effects on local people. A longer period of open water in summer due to later freeze-up and earlier breakup was described as being beneficial by many participants in the three communities. Boats can often cover distance faster than snowmobiles and during the later stages of ice breakup many hunters eagerly await enough open water to use boats. At such times more rapid breakup is beneficial. In fall, too, boats offer an effective means of hunting and accessing harvest areas. However, boats are more expensive to purchase, maintain, and supply with fuel than snowmobiles. Hence, only those residents with financial ability to use and access boats can take advantage of changing conditions. In this manner, changing conditions can contribute to increased community inequality (Ford et al., 2008).

### *SOCIOECONOMIC STRESSES*

Changing ice conditions as documented by community members and captured in instrumental data sets are a recent phenomenon in the case study communities and are occurring in the context of longer term changes in the extent, type, and nature of human use of the ice. This has been driven by a complex web of factors surrounding development and cultural adaptations in northern regions. Sociocultural changes—starting with contact with whalers, missionaries and fur traders, and advanced by the policies of the federal government and integration into national and international markets—have affected use of the ice predominantly in Igloolik and Ulukhaktok, including what technology is used and degree of risk-taking behavior. These trends were not noted in interviews in Churchill, although further research is required to explore the role of socioeconomic change in shaping exposure in this community.

#### *Hunting Technology*

There has been profound change in technology used in harvesting in the case study communities. Snowmobiles have been widely used since the 1960s and 1970s, when they replaced dog teams and walking as the main form of transportation. More recent technological developments include the use of very high frequency (VHF) radios, global positioning systems (GPS), satellite phones, personal location beacons, and the use of weather forecasts over the internet and television. The adoption of these modern technologies has occurred in the context of decreasing time availability for hunting due to participation of hunters in the formal economic sector, the requirements of hunting with snowmobiles, and the perceived safety that many of these devices provide (Ford et al., 2006a). Additionally, in Igloolik and Ulukhaktok the concentration of formerly semi-nomadic hunting groups in fixed communities by the federal government policy beginning in the 1960s also played a major role in forcing residents to adopt new technology by reducing hunting flexibility vis-à-vis the location of wildlife species.

In Igloolik and Ulukhaktok, participants described the adoption of new technology and equipment as having implications for safety when using the ice for hunting and/or travel. On the one hand, if used properly, they confer improvements in safety and reduced hazard exposure in terms of potential for loss of life and serious injury. VHF radios and satellite phones allow the community to be contacted in case of an emergency, personal location beacons have saved lives by enabling rescue teams to locate lost or injured hunters, GPS permits navigation in near zero visibility, snowmobiles allow land to be reached rapidly if the ice disintegrates, and weather forecasts allow residents to judge safety of using the ice. Local search and rescue groups also make use of this technology in emergency situations, and it enables resources from southern regions to be drawn upon in search and rescue operations, including helicopters, planes, and logistical support (George, 2000; CBC, 2005). A community member in Ulukhaktok describes an incident when her husband was stranded on the land when his snowmobile became stuck in mud during a rapid spring melt.

> "He had a GPS … I guess it's just the signal to pin-point him just in case something happens that he doesn't know where he is … he called [with his satellite phone] and said that he needs help, so I called around and got some people and they went out to get him…."
>
> Anonymous, Ulukhaktok, 2005

Technology, however, has created new risks and exacerbated old ones (Ford et al., 2006b). The replacement of dog teams with snowmobiles, for instance, has increased the dangers of traveling on ice: snowmobiles cannot sense dangerous ice or travel over very thin ice. Snowmobile travel is particularly dangerous in fall when there is snow-covered thin ice, exacerbated in recent years with changing ice conditions in fall. Since the introduction of snowmobiles, accidents have been documented involving hunters falling through thin ice that they were not able to identify; these accidents would probably have been avoided with dog teams.

> "The dog teams know the thin ice and the thicker ice …. Snowmobile doesn't say, 'Alert! This is thin ice.' So it's more dangerous [by snowmobile] than by dog team."
>
> H. Paniaq, Igloolik, 2004

Snowmobiles also enable community members to travel longer distances in a shorter period of time. In Igloolik and Ulukhaktok, adult community members expressed their concern for community youth who often travel with minimal supplies and warm clothing assuming that they will return to the community with ease, unaware of potential mishaps such as a mechanical failure in their snowmobile, an accident, or poor weather conditions.

In Igloolik, community members expressed concern regarding the widespread use of GPS and its implications for safety while hunting. GPS was first introduced in the 1990s, but had limited use until 2000 when the Hunters and Trappers Association made user-friendly devices available at subsidized cost. GPS is now in widespread use. Concern was expressed regarding the perception of safety among its users. GPS allows successful travel with limited knowledge about navigation and the environment (Aporta and Higgs, 2005). Consequently, young and inexperienced hunters can now travel alone or in absence of more experienced hunters and to locations where they would not have previously gone.

> "We go to areas where we wouldn't normally go because we are assured [by the GPS] we will know where we are."
>
> N. Arnatsiaq, Igloolik, 2004

> "Like if there is thin ice and it makes you go straight where you want to go you got to be aware of thin ice you will go through. GPS is making you go straight, up steep hills you just go through them."
>
> L. Uttak, Igloolik, 2006

> "GPS enhances your navigation, but if it runs out of batteries it doesn't enhance navigation, it disables you. It can be your blessing and your downfall at the same time"
>
> T. Ikummaq, Igloolik, 2004

While GPS is being used in Ulukhaktok, it is largely used as a back-up navigation device and is not in widespread use like Igloolik. Numerous reasons for this can be offered, including the lack visual distinctiveness in the terrain near Igloolik compared to the more rugged landscape near Ulukhaktok where there are more landmarks to use in navigation. Igloolik has also benefited from the presence of the Nunavut Research Institute which has played an important role if helping hunters adopt and learn how to use new technology. The negative impacts of GPS use on safety, documented in Igloolik, were not noted in Ulukhaktok or Churchill.

*Risk-Taking Behavior*

Risk assessment when making decisions regarding hunting has also changed in other ways; residents in Igloolik and Ulukhaktok are now more likely to harvest in spite of poor weather or ice conditions. This is partly due to the reduced time available to harvest. Many hunters now balance full- or part-time jobs with hunting activities and as Ford et al (2006b) argued, time off from work, which is used for hunting trips, has to be booked weeks, if not months, in advance. Weather or safety concerns may, therefore, be superseded by consideration of time availability when harvesting decisions are made.

> "I think some people will now go out [hunting] when they wouldn't normally go out."
>
> J. Ungalak, Igloolik, 2006

> "It's tough with work trying to plan for weekends and if weekends are bad [weather or ice conditions] … most of the time it seemed like the weekends were bad weather and the week days were good … sometimes we have to go anyways."
>
> Anonymous, Ulukhaktok, 2005

More risk-taking behavior is also associated with technological developments. Interviews in Igloolik and Ulukhaktok indicated that VHF radios, the functioning of a community search and rescue group, and in Igloolik the use of GPS, which provide a safety net if problems are encountered, have resulted in less caution and overconfidence. Hunters are now traveling and hunting in conditions that would have traditionally been considered dangerous (e.g. compare today with Beaubier et al., 1970) at the same time that changes in the physical environment are increasing the dangers of risk taking, exposing hunters to the potential for injury, loss of life, or damage to hunting equipment.

> "[With these new technologies] we take more chances."
>
> N. Arnatsiaq, Igloolik, 2004

Risk-taking behavior in Igloolik and Ulukhaktok is also linked to a loss of land-based skills and incomplete transmission of knowledge for safe hunting among youth. Many younger generations face challenges in gaining practical experience on the land where survival and safety skills, and other forms of traditional knowledge are developed through active engagement, observation, and language (Henshaw, 2007). Consequently, skills including the ability to locate dangerous areas on the ice, identify precursors to hazardous conditions, cope with hazard encounters, or judge whether it is safe to go hunting, have been lost or incompletely transferred, thereby increasing risk-taking behavior (Ford et al., 2006a). It is also more common for young people to go out on the land without proper clothing and/or supplies; as a result, they are not equipped to deal with changing conditions that may delay their return to the community or put them in unsafe situations. Changing ice conditions compound the implications of risk-taking behavior. This is reinforced by equipment such as snowmobiles and new technology, which enables young hunters to go hunting without the years of experience required to operate a dog team and navigate using traditional wayfaring methods (MacDonald, 1998; Aporta and Higgs, 2005).

> "Now people travel so quickly and fast and the ones that are staying behind are easily worried because they do not have the same frame of mind of how their elderly used to travel."
>
> A. Akoakhion, Ulukhaktok, 2005

> "Young people go out on the land in everyday jackets—they get cold more easily. They go for appearance …. [If young people] get stranded on the land, they can't make snow shelters and searchers have to go for them. Older adults should be taking out young people, teaching them survival on the land."
>
> I. Kuneyuna, Ulukhaktok, 2005

Concern over youth and their exposure to hazards is widespread in both communities with many interviewees noting that many accidents on the land involve young generations. Moreover, with 76% of Igloolik residents and 65% of Ulukhaktok residents under the age of 34, young people are increasingly becoming the main users of the land, a trend with future consequences for hazard exposure (Statistics Canada, 2006).

*HAZARD INDICATORS*

An understanding of the determinants of hazard exposure can help contribute to the development of indicators to identify and monitor changes in physical and social drivers over time. Monitoring such indicators can facilitate a characterization of changing hazard exposure in response to changing environmental and/or socioeconomic conditions. Community members in all three communities identified and characterized the nature of physical conditions which present risks while hunting or traveling. These conditions can form the basis of real-time monitoring. For example, air temperature during fall is particularly important, controlling not only when the ocean freezes but also how long it takes to freeze to a certain thickness. Snowfall during freeze-up is also an important condition, potentially slowing down the freeze-up process and hiding thin ice. Other, more difficult to monitor conditions that determine safety of ice use include ice thickness along key trail routes, and ice structures (i.e. presence of cracks at key locations). A number of social drivers which determine how physical conditions are experienced and which shape vulnerability can also be monitored; although social drivers are more difficult to measure given the low frequency of data collection on social indicators. Potential indicators could include: documenting the number of accidents related to sea ice use, and assessing if this is increasing; identifying if certain groups are highly represented in the data; and identifying the causes for accidents with the aim of providing insights into changing vulnerability trends. It is noteworthy that these are not a comprehensive set of indicators, and are included here to give direction regarding what such indicators might include and how they might be developed.

## Discussion and Conclusion

Of all the changes in the Arctic environment documented in recent years, changes in the ice stand out prominently. Trends observed at a circumpolar scale are reflected in ice conditions in northern Canada, with later freeze-up, earlier breakup, ice thinning, and altered ice dynamics captured in local and regional instrumental data sets and in traditional knowledge in the three case study communities. These changes have affected the use of ice for hunting and travel, reduced access to hunting areas, and increased the dangers of using the ice in all seasons. These trends are also having negative psychological impacts by stressing traditional food systems and affecting community sociocultural dynamics. These findings are supported by research elsewhere in northern Canada (Blakeney and Suluk, 2006; Duerden and Beasley, 2006; Furgal and Seguin, 2006; Gearheard et al., 2006; Nickels et al., 2006; Tremblay et al., 2006). Comparison between the communities, however, reveals the uneven consequences of changing ice conditions on hazard exposure, a function of the nature of ice use, local physiographic setting, and community sociocultural dynamics.

The uneven consequences of changing ice conditions are evident in the seasonal differences in which community members describe increasing exposure. Users of the ice in Igloolik and Ulukhaktok are sensitive to later and longer freeze-up in fall on account of their reliance on the ice to access hunting areas, Igloolik due its location on a small island, Ulukhaktok due to the rugged landscape. People are still using the ice at this time despite the dangers as many rely on hunting and the products it provides for their livelihoods. Particularly for those who hunt full-time and/or have limited access to money, avoiding using the ice by substituting traditional food with store food is an option many do not consider due to financial constraints. In cases where ice conditions prevent hunting or travel, food security and the sociocultural value of eating and sharing traditional foods are compromised (Ford, in press). This is an important dimension of hazard exposure often overlooked in the literature (see Ford et al., 2008). Churchill residents are less dependent on traditional foods, balancing hunting with waged employment and consumption of store food. People in Churchill are more able to manage the increasing dangers of using the ice in fall by waiting in the community until it is safe.

Ice use in Churchill is sensitive to changing ice conditions in spring. Goose hunting grounds in spring are located north of the Churchill River. Climate change has exacerbated the risks of traveling on the ice at this time, with strong winds and warm weather making the ice difficult to predict. Goose hunting is an important activity in the community and the dangers posed by changing ice conditions have, to date, been accepted by community members. Duck hunting is an important spring activity in Ulukhaktok, and thinner ice conditions have resulted in accidents and reduced harvesting success. In Igloolik most hunting in late spring occurs at ice leads in close proximity to the community thereby limiting sensitivity to changing ice conditions. This enables hunters to return quickly to the safety of land if hazardous conditions are encountered and obtain help rapidly if an accident occurs. Proximity also increases accessibility by reducing travel time to hunting areas. Hunters can therefore regularly assess ice conditions and opportunistically take advantage of local conditions as they arise; this is much more difficult for distant hunting areas which entail long travel times and the possibility of making only a few trips.

The uneven consequences of changing ice conditions are also evident in the nature in which exposure is changing. In Igloolik and Ulukhaktok, the implications of recent changes in ice conditions are being exacerbated by longer term changes in how people use the ice, a consequence of changing community dynamics and new hunting technology. This is reflected in community description of losses and injury associated with changing ice conditions and associated psychological impact. Churchill has also witnessed social, cultural, and technological changes, but it appears they have had a limited role in affecting how community members perceive and experience climate change; although further research is required to substantiate this claim. We offer a number of preliminary explanations. First, it is partly related to the status of hunting in the community, with more community members participating in wage economy and balancing store food with traditional foods, particularly at recognized dangerous times of the year. Technology such as GPS is therefore less likely to be used to enable hunting or travel to take place during bad weather, and people are more cautious about taking risks if the ice conditions are sub-optimal. Second, in Churchill fewer people use the ice for hunting or travel, which is largely limited to experienced and generally more mature hunters compared to Igloolik and Ulukhaktok where hunting is widely practiced among most social and age groups. The trend towards increased risk-taking among youth that technology has facilitated in these two communities is less evident in Churchill, where youth are more involved in the formal wage-based economy and partake less in using the ice.

These conclusions have important ramifications for research assessing the potential implications of future climate change on hazard exposure in general and northern Canada in particular. They point to the importance to focusing on physical stimuli directly relevant to local livelihoods, particular if the aim of the research is to reduce community vulnerability. They underscore the importance of place-based research. Climate change is being, and will be, experienced differently according to how people use the ice. This research demonstrates that the impacts of climate change will not occur in isolation but in the context of community sociocultural dynamics which can exacerbate or moderate the impacts of changing ice conditions. Identifying and characterizing non-climatic drivers of vulnerability offers an entry point for policy to mitigate hazard exposure. These findings, discussed here in a northern context, are increasingly being recognized in the climate change vulnerability field in general (Leichenko and O'Brien, 2002; Turner et al. 2003; Belliveau et al., 2006; Eakin and Luers, 2006; Smit and Wandel, 2006; Liu et al., 2007).

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