

RESEARCH/REVIEW ARTICLE

Community vulnerability to climate change in the context of other exposure-sensitivities in Kugluktuk, Nunavut

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Climate change; Arctic; community vulnerability; adaptation; Inuit.

CorrespondenceBen Bradshaw, Department of Geography, University of Guelph, 50 Stone Road East, Guelph, Ontario N1G 2W1, Canada.
E-mail: bbradsha@uoguelph.ca**Abstract**

Climate change in the Canadian north is, and will be, managed by communities that are already experiencing social, political, economic and other environmental changes. Hence, there is a need to understand vulnerability to climate change in the context of multiple exposure-sensitivities at the community level. This article responds to this perceived knowledge need based on a case study of the community of Kugluktuk in Nunavut, Canada. An established approach for vulnerability assessment is used to identify current climatic and non-climatic exposure-sensitivities along with their associated contemporary adaptation strategies. This assessment of current vulnerability is used as a basis to consider Kugluktuk's possible vulnerability to climatic change in the future. Current climate-related exposure-sensitivities in Kugluktuk relate primarily to subsistence harvesting and community infrastructure. Thinner and less stable ice conditions and unpredictable weather patterns are making travel and harvesting more dangerous and some community infrastructure is sensitive to permafrost melt and extreme weather events (e.g., flash floods). The ability of individuals and households to adapt to these and other climatic exposure-sensitivities is influenced by non-climatic factors that condition adaptive capacity including substance abuse, the erosion of traditional knowledge and youth suicide. These and other non-climatic factors often underpin adaptive capacity to deal with and adapt to changing conditions and must be considered in an assessment of vulnerability. This research argues that Northern communities are challenged by multiple exposure-sensitivities—beyond just those posed by climate—and effective adaptation to climate change requires consideration if not resolution of socio-economic and other issues in communities.

Anticipated climate changes for the Canadian Arctic are outlined in the *Arctic climate impact assessment* (Kattsov & Kallen 2005), the *Fourth assessment report* of the Intergovernmental Panel on Climate Change (Anisimov et al. 2007) and the government of Canada's national climate change assessment report (Furgal & Prowse 2008). Future warming and increases in precipitation are expected to lead to continued reductions in sea-ice thickness and extent, increased permafrost degradation and coastal erosion and changes in flora and fauna

movement and abundance. These changes, many of which have already been documented by instrumental records and local observations (e.g., Huntington & Fox 2005; Nickels et al. 2006; Perovich et al. 2008; Stroeve et al. 2008), have implications for ecosystems and the humans that inhabit them and pose challenges for Northern communities (e.g., Nuttall 2001, 2005; McCarthy & Martello 2005; Ford et al. 2006a, Ford et al. 2006b; Furgal & Sequin 2006; Gearheard et al. 2006; Lynch & Brunner 2007; Schneider et al. 2007;

White et al. 2007; Andrachuk 2008; Burek et al. 2008; Hovelsrud et al. 2008; Ford 2009a, b; Huntington 2009; Parkinson & Berner 2009; Prowse et al. 2009; Zhou et al. 2009; Pearce, Ford et al. 2010; Pearce, Smit et al. 2010).

For a host of reasons, the assessment of the implications of climate change for Northern communities is a challenging task. Frequently, such assessments start with anticipated or even observed changes in certain environmental variables relative to some baseline condition (e.g., Carter et al. 1994; Gornitz et al. 1994; Symon et al. 2005; Parry et al. 2007). However, assessing what is a “new” condition in the Arctic context is difficult as the coverage of both Inuit and instrumental records face certain limitations. Inuit direct observation is limited by the age of the respondent, depth of traditional knowledge that they have learned, his/her relative experience operating in the local environment and his/her recollection. Furthermore, daily weather records for some communities in northern Canada have only been available since the late 1970s. While this “missing baseline” against which change can be assessed is problematic with respect to climatic conditions, it is even more problematic with respect to non-climatic conditions like social well-being. In the absence of such a baseline, it is clearly not safe to assume that these communities are—or were until very recently—well adjusted to pre-change conditions; indeed, over at least the last century, Inuit communities have been challenged and have had to respond to a great deal of change and continue to do so today. These are dynamic systems under investigation.

Increasingly, research that seeks to understand the vulnerability of communities, in the Arctic and elsewhere, to climatic change consider the effects of climate change together with a host of other non-climate related exposure-sensitivities (e.g., Eriksen et al. 2005; Belliveau et al. 2006; Ford et al. 2006a; Ford et al. 2006b; Parkins & MacKendrick 2007; Tschakert 2007; Forbes 2008; Keskitalo 2008; Pearce, Smit et al. 2010; Young et al. 2010). These empirical case studies build on vulnerability theory that stresses the importance of considering “multiple exposures” in climate change vulnerability assessment (e.g., Liverman 1986; Blaikie & Brookfield 1987; Cutter & Solecki 1989; Bohle et al. 1994; Adger & Kelly 1999; O'Brien & Leichenko 2000; Smit & Skinner 2002; Adger 2006).

In the current context of the Canadian north, a particularly relevant non-climatic exposure for many communities has been the recent boom in resource extraction activities focused on energy, metals and minerals including diamonds (Mining Association of Canada 2009). While such development offers opportunities for many, especially when accompanied by progressive

Impact and Benefit Agreements (Galbraith et al. 2007), it undoubtedly compounds climate-induced exposure-sensitivities by placing additional demands on the natural environment, community institutions and infrastructure. Other significant changes underway in the Canadian north include, for example, the increasing penetration of a Southern, wage-based, economy and associated cultural change; on-going self-government processes; long-standing and emerging health concerns and locally specific environmental and social issues. It is increasingly accepted that efforts to understand the vulnerability of Arctic communities to climate change must do so in the context of multiple exposure-sensitivities experienced at the community level (Nuttall 2001; Duerden 2004; Ford & Smit 2004; McCarthy & Martello 2005; Keskitalo 2008), while recognizing that the interactive effect among exposure-sensitivities is still not clear, let alone the identification of the most effective means for addressing them.

This paper seeks to contribute to the growing body of research focused on community vulnerability to multiple exposures based on a case study of the hamlet of Kugluktuk in Nunavut, Canada. Consistent with the view that climatic changes will be experienced and responded to in a multiexposure-sensitivity environment and, hence, must be assessed in such a context, this analysis is undertaken based on the “vulnerability approach” (Turner et al. 2003; Ford & Smit 2004; Smit & Wandel 2006). The broad purpose of this approach is to document the ways in which agents or, as applied in this context, communities are sensitive to changing conditions and the ways in which they deal with these changes. Most significantly, these changing conditions are not assumed a priori but rather identified on the basis of people’s experiences, thereby allowing for the identification of differentiated vulnerabilities across and within communities. Understanding existing sensitivities and adaptations not only helps to identify needs and practical opportunities for future adaptation but is also seen as a useful and perhaps necessary basis for envisaging future vulnerabilities (Smit & Wandel 2006). This paper predominately focuses on current sensitivities and adaptations in the community of Kugluktuk, although it draws on this evidence and other sources of knowledge to consider future vulnerabilities.

The next section of the paper briefly reviews past research focused on climate change impacts and adaptations, with particular focus on the vulnerability approach as used in both Arctic and non-Arctic settings. Following this, the Kugluktuk case study is described with respect to both community characteristics and the methods of investigation. The paper’s core empirical findings and

related arguments are then presented in three subsequent sections: first, current climatic exposure-sensitivities are identified along with their associated contemporary adaptation strategies; second, other non-climatic exposure-sensitivities are identified along with their associated contemporary adaptation strategies and third, the future vulnerability of Kugluktuk to climate change, in the context of multiple exposure-sensitivities, is considered. Finally, some conclusions are offered.

Climate change impacts, adaptation and the “vulnerability approach”

Human adaptation to climate change as a research focus emerged along with growing awareness of anthropogenically induced climate warming (Smit & Wandel 2006). Early studies with an explicit adaptation angle generally took the form of estimating the anticipated impact of specified climate scenarios or ranges of scenarios on particular regions or economic sectors (Symon et al. 2005; Brklacich et al. 2007). In these studies, which are sometimes referred to as “impact-based”, “first-generation” and/or “outcome vulnerability”, vulnerability is generally treated as the residual impact of climate change after adaptation has been accounted for (Fussel & Klein 2006; Brklacich et al. 2007; O’Brien et al. 2007).

The Intergovernmental Panel on Climate Change’s *Fourth assessment report* (Parry et al. 2007) and more recent conceptualizations of vulnerability in the human dimensions of global change community take a broader view of the concept to include the multiple exposure-sensitivities including climate change, which affect a community, region or sector of interest (Fussel & Klein 2006; Schneider et al. 2007). A key distinction in this so-termed vulnerability approach is the view that climate impacts do not cause vulnerability; rather, climate change is seen as yet another factor that affects the security and well-being of communities (Ford & Smit 2004; Fussel & Klein 2006; Smit & Wandel 2006). Furthermore, these second generation studies recognize that human communities encompass complex and dynamic management strategies and that climate change responses occur in the context of a myriad of other decisions. This approach is particularly apt for research focused on the Canadian Arctic given the region’s rapid transition from subsistence-based semi-nomadic societies to sedentary communities that have integrated aspects of Southern wage economies.

Generally, second-generation impact assessments treat vulnerability as a function of exposure, sensitivity and adaptive capacity (McCarthy et al. 2001; Fraser et al. 2003; Turner et al. 2003; Ford & Smit 2004; Smit & Wandel 2006). Exposure and sensitivity (frequently

expressed as the compound term exposure-sensitivity) depend on the interaction between humans and attributes of climate, with the former frequently used to refer to the presence of potentially problematic conditions and the latter reflective of the occupancy and livelihood characteristics that make individuals and communities susceptible to these exposures (Smit & Wandel 2006). Adaptive capacity is the ability to manage exposure-sensitivities via adaptive strategies, which can range from reactive coping mechanisms to long-term planning for anticipated climate change (Smit et al. 2000). At the community level, adaptive capacity is related to both local determinants—e.g., availability of human and financial capital, access to technology, local institutions—and the larger context within which the community operates—e.g., the terms of self-government in Nunavut and federally sponsored programmes fostering adaptation (Bohle et al. 1994; Yohe & Tol 2002; Adger 2006; Ford et al. 2006a).

Climate change vulnerability and adaptation research in the North American Arctic has long recognized the need to consider not just a stimulus or risk (i.e., a particular suite of climate scenarios) but how these climate-related changes are translated into impacts at the community level. In particular, scholars have highlighted the need to include indigenous and local knowledge in impact assessments (e.g., Riedlinger & Berkes 2001; Duerden 2004; Nichols et al. 2004; Gearheard et al. 2006; Nickels et al. 2006; Tyler et al. 2007; Forbes 2008; Pearce et al. 2009). Furthermore, research in the Arctic has frequently been framed in the context of socio-economic changes and adaptation to non-climatic exposure-sensitivities (e.g., Condon et al. 1995; Hamilton et al. 2000; White et al. 2007; Forbes 2008). Recent work has been explicitly framed using a vulnerability approach (e.g., Furgal & Seguin 2006; Tyler et al. 2007; Andrachuk 2008; Ford et al. 2008; Hovelsrud & Smit 2010; Pearce, Smit et al. 2010) or has included these concepts in the language of socio-ecological resilience (e.g., Berkes & Jolly 2001; Chapin et al. 2006).

Consistent with methodological principles outlined in the Arctic vulnerability studies cited above as well as the work of the broader human dimensions of global change community (e.g., Turner et al. 2003, Keskitalo 2004; Lim et al. 2004; Fussel & Klein 2006), research completed in Kugluktuk was guided by the vulnerability approach used in the International Polar Year project Community Adaptation and Vulnerability in Arctic Regions as outlined by Smit et al. (2008). This approach begins with a documentation of the actual conditions that are or have been problematic for the community (exposure-sensitivities) and the adaptations that have been or are being employed

to try to manage these (adaptive strategies). Based on this specification of current vulnerability, researchers then project future vulnerability via identifying future exposure-sensitivities (e.g., through climate forecasts) and factors that are expected to enhance or constrain future adaptive capacity.

A crucial aspect of vulnerability assessment is to gather and understand the stakeholders' own information on their exposure-sensitivities and adaptive capacity, which requires researchers to develop relationships with communities (Pearce et al. 2009). Researchers also draw on other sources of information including meteorological data, government reports, newspaper articles, published scholarly sources and projections from relevant climate models to build a comprehensive understanding of the local implications of climate change and adaptation options.

Case study: Kugluktuk, Nunavut

The community

The Hamlet of Kugluktuk (formerly Coppermine) is the westernmost community in the Canadian Territory of Nunavut at $67^{\circ} 49.5''$ N, $115^{\circ} 5.75'$ W (Fig. 1). Approximately 92% of the community's 1300 residents are Inuit and just over half the hamlet's population is under 25 years of age (Statistics Canada 2007). All communities in Nunavut are remote and must be accessed by air or sea.

Kugluktuk is served by two daily scheduled flights operated by First Air and Canadian North via Yellowknife and once-yearly fuel and cargo barges using the Mackenzie River route. Consequently, bulk goods and fuel (for power generation, heating and transportation) needs must be planned for over a year in advance, with costly air cargo supplementation (e.g., perishable foods) throughout the year. The average monthly precipitation and temperature based on 1971–2000 norms are shown in Fig. 2, with an average of 249.3 mm of precipitation per year (Environment Canada 2010). The freeze-up date norm for the Kugluktuk region is late October and the break-up date norm is mid- to late June (Duguay et al. 2006). From October to April, the prevailing wind direction is south-west and in the summer months (May to September) the prevailing wind direction is east (Environment Canada 2010).

Kugluktuk was established as a permanent Inuit settlement in the mid-20th century adjacent to Hudson's Bay Company's Coppermine trading post. Until government-sponsored settlement, the area's Copper Inuit practiced a semi-nomadic way of life with a high reliance on terrestrial and marine mammals. Permanent settlement was accompanied by the introduction of a Southern school curriculum, the wage-based economy and exposure to mass media. In particular, satellite television, internet and mobile communications have changed the community in recent years. The local dialect is Inuinnaqtun and is spoken by older generations and some young people but English is readily used in the

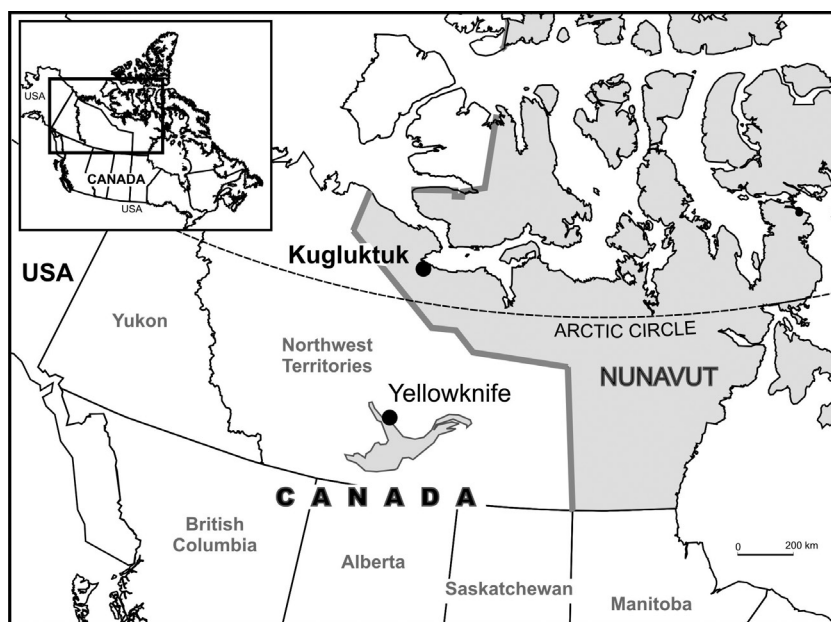


Fig. 1 Map showing the location of Kugluktuk, NU.

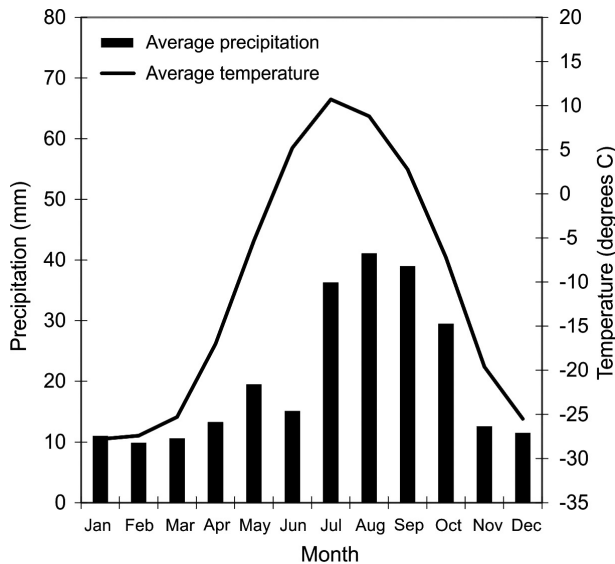


Fig. 2 Average monthly precipitation and temperature at Kugluktuk, NU, for the period 1971–2000. (Source: Environment Canada 2010.)

community. While cultural change has been significant (with many positive and negative repercussions), community members still retain traditions that are closely linked to the semi-nomadic past. Going out “on the land”, a term used by Inuit to refer to any traditional activity such as hunting, camping or travelling that takes place outside the settlement on either land or the sea is still practiced by many community members. Hunting and harvesting retain social, cultural and economic significance for Inuit and caribou, musk ox, moose, geese, ringed seal, Arctic char and lake trout comprise key traditional food sources.

Case study research methods and logistics

This case study research was consistent with the approach to vulnerability assessment outlined above. The research was designed to gain insights into the nature of current vulnerability to climate change in the context of multiple exposure-sensitivities at the community level in Kugluktuk and use this as a basis to examine possible future vulnerabilities. The primary method of data collection for achieving this goal was semi-structured interviewing, which was completed by one male interviewer from a Southern university in collaboration with Inuit research partners over an eight-week period in summer 2007. Interviews were completed with a sample of 31 male and female community members (84% Inuit) ranging in age from 18 to over 70. Semi-structured implies that the interviews followed a standard or replicable protocol to elicit responses on changes the community was exposed to and the adaptive strategies

undertaken by community members to deal with those changes but were flexible enough to allow for additional questions and even alternative lines of “conversation” to accommodate the interests of respondents (Huntington 1998). Semi-structured interviews have been widely used in human dimensions of climate change research throughout the Arctic that seeks to collect information in an open-ended format (e.g., Berkes & Jolly 2001; Gearheard et al. 2006; Tremblay et al. 2006; Ford et al. 2008; Laidler et al. 2009; Pearce, Smit et al. 2010). Major interview themes are highlighted in Table 1.

Respondents were selected using purposive, snowball and convenience sampling methods in an attempt to obtain an illustrative sample of gender, age groups and areas of expertise (Bradshaw & Stratford 2000). Members of the community who were engaged in wildlife harvesting or other commonly practiced activities were targeted, as were members of other demographic groups such as women, elders and youth. Suggestions regarding potential interviewees were often made to the researcher by community members. More men than women were interviewed over the course of the research (65% of those interviewed were men) but this was not done intentionally. Two potential reasons for this gender imbalance include the increased comfort of men talking with a male researcher and/or more males than females were identified as having extensive knowledge of local

Table 1 Major interview themes and example questions asked under each theme.

Interview theme	Example questions
Background information	<ul style="list-style-type: none"> ● Age/sex ● Years in community ● Activities involved in
Current changes	<p><i>Open-ended and unprompted</i></p> <ul style="list-style-type: none"> ● Have you seen any changes in Kugluktuk? Which ones? ● How do these changes affect you? ● How do you deal with these changes? <p><i>Directed questions—environmental/climate change</i></p> <ul style="list-style-type: none"> ● Have you seen any changes in: <ul style="list-style-type: none"> –ice conditions –winds or storms –wildlife –other? ● How do these changes affect you? ● How do you deal with these changes?
Future challenges	<ul style="list-style-type: none"> ● Do you see some of the changes we talked about continuing to be a problem? ● Are you concerned about climate change impacts? <ul style="list-style-type: none"> –Which ones? –What resources does the community have to adapt?

environmental conditions. A similar male bias in the research sample has been recorded in climate change vulnerability assessments elsewhere in the Arctic (e.g., Pearce, Smit et al. 2010). A guide was used to structure the interviews to allow respondents to identify items relevant to them with modest prompting to enable elaboration and fact verification. This approach resulted in the use of both broad open-ended questions such as “have you seen any changes in Kugluktuk?” and follow-up more narrow and deliberate questions such as “have you seen changes in the timing of ice break-up?”

The interviews were facilitated by Inuit research collaborators—summer students working for the local Hunters and Trappers Association—who helped manage local publicity and initiated contact with potential interview participants. The local collaborators guided research activities in the community including ensuring that the interview schedule did not interfere with community events and that research activities were undertaken in a locally appropriate manner. Interviews were primarily conducted in English, though Inuinnaqtun translation (via a paid community interpreter) was available and used by some of the older respondents. Interviews usually took place at the residence of the respondents, although some were conducted at their place of work. These interviews were supplemented by day trips on the land with community members and numerous informal meetings with both key informants and other community members.

Given that one field season alone cannot provide a complete understanding of community vulnerability, some potential knowledge gaps were addressed by making use of multiple and varied data sources. Beyond community data sources, other sources of information that were drawn upon included the meteorological record (since 1978), government reports, newspaper articles, published scholarly sources and projections from relevant climate models.

Climatic exposure-sensitivities and adaptations in Kugluktuk

Consistent with research in other communities across the circumpolar north, there is widespread recognition by residents in Kugluktuk that climatic conditions are changing. Nearly all of the case study participants described a story of “weird weather” and/or “unnatural” or “changing” environmental and climatic conditions. Changing environmental and climatic conditions are commonly felt when people are “out on the land” engaged in subsistence harvesting activities. Consequently, many climate-related exposure-sensitivities relate to travel, weather forecasting

and wildlife behaviour, although some have implications for the hamlet itself, in particular with respect to infrastructure. A summary of these exposure-sensitivities is presented in Table 2; the table also identifies related adaptations and remaining vulnerabilities for both climatic and non-climatic phenomena, all of which are described in this and the subsequent two sections.

Travel on land and ice

One of the primary areas of concern related to climatic variables is the ease and safety of travel on the land and ice. Ice (both sea ice and inland lakes) has been noted to form later in the season and melt earlier and the ice coverage is thin and incomplete. Likewise, Duguay et al. (2006) identified a weak trend towards later freeze-up dates and earlier break-up dates for lakes in this region for the period 1966–1995. Similar observations have been recorded elsewhere in the Arctic including in Ulukhaktok, NWT (Pearce, Smit et al. 2010), in Clyde River, NU and Barrow, AK (Gearheard et al. 2006) and in Igloodik, NU (Laidler et al. 2009). Freeze-up and break-up are some of the most dangerous times to travel on the sea ice. Travel on the ice is inherently dangerous but thinner ice conditions, incomplete ice coverage and less predictable freezing and thawing times have made travel on the ice increasingly hazardous. For example, two Kugluktuk elders died as a result of their snowmobile breaking through thin ice in 2005 and in 2006 two youths lost their lives after deciding to take a short-cut over candle ice (rotten ice that develops in columns perpendicular to the surface). Furthermore, with changing ice dynamics, pressure cracks in the ice are now forming in different areas than in the past, challenging traditional knowledge of local ice conditions. Water is also now pooling on top of sea ice more frequently and hunters have occasionally become wet because of this, thereby risking the chance of freezing. Travel on the land, in general, was noted to have become “more dangerous” by many of the interview respondents at least partly because of changing ice conditions. However, this is compounded by other factors; in the tragic case of the two youths mentioned above, a third youth survived because he chose not to take the short-cut route, which he knew to be riskier. In this case, unsafe ice conditions interacted with changing knowledge and risk-taking behaviours, a relationship documented by Berkes & Jolly (2001), Aporta (2002), Ford et al. (2006a), Pearce, Smit et al. (2010) and others. According to Kugluktuk Conservation Officer Allan Niptanatiak, people with insufficient travel knowledge and survival skills have ventured out on the land “blindly

Table 2 Summary of exposure-sensitivities, adaptations and key remaining vulnerabilities, Kugluktuk, NU.

	Relevant exposure-sensitivities	Adaptations to exposure-sensitivities	Key (remaining) vulnerabilities
Climatic	<ul style="list-style-type: none"> ● Changing ice, precipitation, winds and weather norms <ul style="list-style-type: none"> – Ice forming later in the season and melting earlier and generally thinner – Less snow in winter and melts earlier – Snow quality has changed, with more deep and hard-packed snows – Increased incidents of freezing rain in the winter – Unusual winds with respect to both intensity and dominant direction – Less predictable weather ... make travel more dangerous ● Permafrost melt and extreme weather has damaged and/or impacted infrastructure (e.g., hamlet roads and all-terrain vehicle trails, building foundations) ● Changing wildlife conditions, e.g., <ul style="list-style-type: none"> – “Southern” species increasingly being found – Altered animal migration and hibernation patterns – Increased incidents of diseased and unhealthy animals ... make harvesting more challenging 	<ul style="list-style-type: none"> ● Alteration of travel routes and timing of travel ● Increased preparedness while on the land via use of weather reports, radios, survival gear (e.g., warm clothes, extra food, stove, tent), navigational devices and by travelling in groups ● Rebuilding and modest reinforcement of damaged infrastructure ● Changes to the timing of harvesting and type of species harvested; sharing occurs when food is not abundant 	<ul style="list-style-type: none"> ● Some changing environmental conditions are posing continued problems for harvesters (e.g., thinning ice, poor weather), resulting in more risk-taking travel ● Community infrastructure not well-adapted to a changing climate
Non-climatic	<ul style="list-style-type: none"> ● Residual exposure from historic changes (e.g., contact with and integration into Western society) ● High unemployment, low education levels, overcrowding of housing, elevated levels of Fetal Alcohol Spectrum Disorder ● Elevated levels of crime, suicide, alcoholism and drug abuse ● Erosion of traditional knowledge among youth ● Increased employment opportunities, namely with regional mineral development ● Signing of the Nunavut Land Claims Agreement has provided Nunavut residents with greater self-government powers (new challenges associated with government and institution building) 	<ul style="list-style-type: none"> ● Teaching traditional knowledge and land skills to younger generations (e.g., traditional knowledge camps; changes to language legislation) ● Increased involvement in the wage economy by residents ● Signing of the Nunavut Land Claims Agreement has provided Nunavut residents with greater self-government powers ● Nunavut Harvesters Support Programme provides financial assistance to purchase harvesting equipment ● Various initiatives by the territory and hamlet to deal with social ills (e.g., Nunavut’s suicide prevention strategy, Kugluktuk’s Grizzlies programme) 	<ul style="list-style-type: none"> ● Traditional knowledge not readily being passed down to younger generations ● Social ills (e.g., crime, poverty, suicide, low education) remain rampant. Mitigating efforts have had limited effects to date, although these efforts continue

following (snowmobile) trails on the ice” without doing their own safety evaluation.

The quality of snow, which constitutes another means of travel in winter, has also changed. As one interview respondent noted: “We don’t have snow like we used to”. While some respondents drew attention to extreme snowstorms that delivered deep and hard to navigate snows, more concern was expressed about insufficient snow. In general, the snow does not last as long into the season as before and areas where snow could be found year round before are now often found bare. This limits travel by snow machine, the primary mode of transportation in winter months. Analysis of the last day with snow on the ground in Kugluktuk from 1978–2007 supports these observations and by showing a statistically significant ($p = 0.00784$) decreasing trend (Fig. 3). A simple linear regression (slope = -0.61224) reveals that, each year, the snow is melting an average of over half a day earlier. In some instances snow found around Kugluktuk has also been forming into harder layers as a result of freeze–thaw in the winter (and particularly if warmer temperatures are accompanied by precipitation) as well as due to freezing rain, which has been hard on snowmobiles. Detailed meteorological records for Kugluktuk help confirm these events and indicate 81 instances of freezing rain since 1978 (Environment Canada 2010). Should freezing rain events increase in the future, the

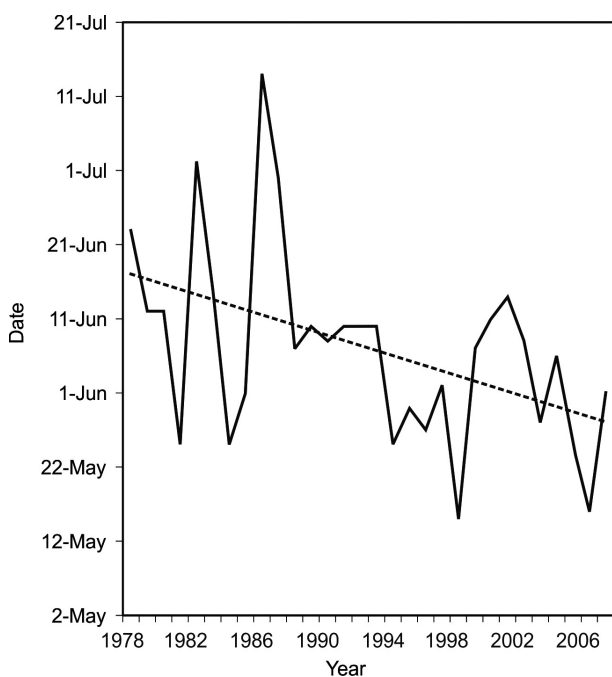


Fig. 3 The last day with snow on the ground in Kugluktuk, NU, for the period 1978–2007. (Source: Environment Canada 2010.)

dangerous possibility of hunters getting wet and freezing during cold Arctic winters may also increase.

In the summer months, when travel is done mainly by boat and the all-terrain vehicle (ATV), travel conditions have also changed. Travelling by boat has become more difficult at times, as winds have been noted to be stronger than usual, forcing parties to remain on the shore or “wind-bound” until the conditions settle down. Owing to employment obligations, dwindling supplies or some other reason, some individuals acknowledged travelling home notwithstanding challenging conditions, though this is hardly a new practice. In this sense, the activity only introduces a new exposure-sensitivity if wind conditions have indeed changed of late.

In addition to altered wind speeds, the direction of the wind is perceived to have changed, which also affects safe navigation, most notably on the land. Inuit in the community most often travel by snowmobile in the winter and sometimes navigate by snowdrifts that form relative to prevailing winds. By knowing the direction of the prevailing wind, travellers can identify the direction they are travelling and follow the snowdrift accordingly. This form of navigation is particularly important when travelling in conditions with poor visibility such as blowing snow and winter darkness. Prevailing winds used to come from certain, known directions; however, winds now often come from unexpected directions in varying intensities. “Winds [come] from everywhere now”, as one experienced hunter, Don Ayalik, noted; navigation by snowdrift has thus become more difficult. Instrumental data show that, for the winter months over the period 1978–2004, the most frequent wind direction was to the south-west (Fig. 4), although potentially relevant short-term fluctuations (e.g., daily, weekly) are not displayed. The data in Fig. 4 come from a single weather station (Kugluktuk) and are not necessarily representative of weather conditions in other areas where community residents travel. However, for the period 2004–07, the wind came from all directions with similar frequency, supporting community views of reduced predictability.

In addition to these perceived shifts in ice, snow and wind “norms”, Kugluktuk residents are experiencing less predictable weather, which is especially problematic for those who regularly engage in subsistence activities. This observation is consistent with the findings of Nickels et al. (2006) from communities elsewhere in the Arctic. One of our respondents noted that in recent years “weather patterns have changed so drastically”. Instead of weather being predictable, now “it’s sporadic ... it’s weird”. These changes are important, as travel plans are inextricably tied to the weather. In recent years unusual winds, rain,

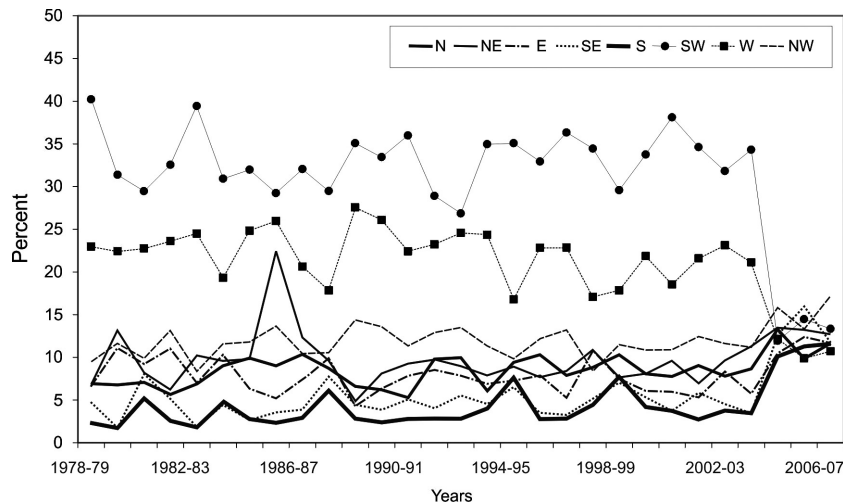


Fig. 4 Wind direction by percentage for winter season (October–April) in Kugluktuk, NU, for the period 1978–79 to 2006–07. (Source: Environment Canada 2010.)

snowfalls and temperatures have been observed. “The clouds in the sky don’t talk to you like they used to”, noted Allen Niptanatiak. “Now, you never know what you’re going to wake up to”, stated David Nivingalok. Historically, Inuit have depended on their knowledge of weather patterns to predict conditions in the near future and ensure safe travel. However, weather prediction is becoming more difficult under changing conditions.

The primary adaptation strategies to changing travel conditions have involved adjusting the mode and timing of travel and the routes taken and making use of new technologies. Similar adaptive strategies have been documented elsewhere in the Arctic (e.g., Berkes & Jolly 2001; Nickels et al. 2006; Tremblay et al. 2006; Ford 2009a,b; Pearce, Smit et al. 2010). A longer ice-free season has meant an increase in the number of days Inuit travel by boat versus snowmobile. At times when ice conditions may be questionable, travellers often opt to stay closer to the shoreline to decrease the likelihood of accidents. If conditions are unsafe, “hunters stay home more now”, states elder Jimmy Hanak. Other respondents pointed out the importance of having patience and taking it day by day to avoid travelling in poor weather. Unpredictable conditions are managed similarly to dangerous conditions; when questionable conditions arise, a common coping strategy is to “wait it out” until conditions are more stable. To this end, travellers have been known to bring tents, sleeping bags, warm clothes, stoves and extra food when travelling on the land. Furthermore, the respondents were nearly unanimous in their view that it was unwise to travel alone; “always travel with someone and always tell someone where you’re going” was a common piece of advice issued to the interviewer.

Inuit in Kugluktuk have also taken advantage of technology to adapt to unpredictable weather. Some hunters will check weather reports online before heading out on the land and tune into long-range radios for weather reports while away from the community. Furthermore, VHF radios are used to keep travellers in contact with the community and can be used to contact the community’s search and rescue committee. In situations where a rescue operation needs to be activated, precise locations can be identified given the increased use of global positioning system (GPS) devices. The GPS is also an important adaptation strategy to the challenges posed to navigation with less reliability in snowdrift navigation due to less predictable wind directions. However, overt reliance on GPS technology also threatens to erode traditional Inuit wayfinding skills and can present new dangers (Aporta & Higgs 2005; Bravo 2009). It is important to note that other travel-oriented adaptations may also increase exposures to new risks. For example, hunters who have adapted by travelling over new routes or during different times of the year may now face risks associated with travelling in unfamiliar territory and weather conditions.

Adjustments in the Inuit’s land travel practices and especially routes have also been driven by permafrost melt and changes in the depth of the active layer, which have affected the quality of ATV trails around Kugluktuk. In some instances these trails are used as a primary means of travel to various locations (e.g., cabins, fishing and camping spots). Large “potholes” and “sinkholes” in the middle of trails have been observed, as has the increased erosion of ATV trails in general. Trails were also noted to be “more boggy” than they used to be with

changes in the active permafrost layer. Some ATV trails outside of town have become impassable because of sinkholes and new routes have therefore developed. Community members have also blamed permafrost melt for increased slumping of river banks and the disappearance of tundra ponds. This latter observation drew national attention (Harding 2007) when scientists discovered that these once perennial bodies of water were disappearing. Tundra ponds play an important role in the Arctic ecosystem because they provide food and water for local wildlife, while also acting as sources of drinking water for Inuit travellers. Interview respondents noted that ponds around Kugluktuk have been drying up in recent years.

Community infrastructure

Permafrost melt combined with altered climatic conditions has also generated problems for community infrastructure in Kugluktuk. For example, parts of the shorelines immediately adjacent to the community have been subject to erosion, a condition that is exacerbated by permafrost degradation, a longer open-water season and associated wave action. Additionally, gravel roads and buildings in town have suffered from changes in permafrost. Hamlet workers noted that roads need more maintenance than in the past and some house foundations are shifting and cracking because of melting permafrost. Beyond gradual melting of permafrost, certain “extreme” weather events have caused considerable damage to infrastructure. For example, in the summer of 2007, the community experienced an unprecedented rain storm. Whereas Kugluktuk receives an average 249.3 mm of precipitation per year, the community received more than half that amount—173.5 mm—in just two days in mid-July (Environment Canada 2010). A number of community members said it was the most rain they had ever seen in the area over such a short amount of time. The instrumental record confirms that the 2007 event was the most extreme precipitation event in instrumental history. The large amounts of rain overwhelmed the community drainage system, causing large-scale erosion of culverts and roads (Fig. 5) and the undermining of the foundations of two houses. Families living in those houses were forced to evacuate by hamlet authorities as there was a fear of house collapse.

Adaptive responses to these infrastructure problems have largely been reactive and minimalist. In the case of shoreline erosion, like Tuktoyaktuk (Andrachuk 2008; Catto & Parewick 2008), the hamlet of Kugluktuk has responded via structural works, using stone riprap to protect some exposed portions of the shoreline. In a

similar fashion, community infrastructure damaged by the 2007 rainstorm, in particular roads and culverts, has been rebuilt to match pre-rainstorm conditions without any obvious modification to engineering design. In the case of housing, damaged homes are repaired where funds are available. However, given limited funds and the high cost of building materials, repair work may be far less than ideal. It is no wonder that, as of the 2006 census, 16.7% of 360 homes in the hamlet were identified as in need of major repairs (Statistics Canada 2007).

Wildlife

Some new wildlife has been observed in the area and the behaviour and movements of some known wildlife have changed. With warmer temperatures and extended ice- and snow-free seasons, wildlife species typically associated with more southerly regions, such as moose, red fox, pike and some bird and insect species, have been observed in and around Kugluktuk. Some community members noted that changing snow and ice conditions have affected caribou migrations and foraging. Caribou have been observed breaking through thin sea ice during their migrations, often dying as they cannot pull themselves out of the water. This scenario has also been documented elsewhere in the Arctic (Sharma et al. 2009). Furthermore, where freezing rain has occurred in the winter, it has formed hard layers of ice on top of the snowpack, thereby preventing caribou from feeding on the vegetation below. Ice-coated ground (e.g., from freezing rain, freeze–thaw cycles) has been noted to affect caribou foraging in other northern locations (e.g., Thorpe et al. 2002; Tews et al. 2007). All these things have implications for caribou hunting communities, like Kugluktuk, who depend on the caribou for food.

The timing of grizzly bear hibernation has also changed and these animals are now being seen at uncommon times of the year and in new areas. Additionally, respondents expressed concern over the timing of the Arctic char runs (or migrations). The summer of 2006 was mentioned by nearly all respondents to be unusually poor for fishing; many wondered whether this change was due to warmer than usual temperatures. One resident highly involved in community wildlife management noted that “water levels in some instances have been decreasing and this has prevented access by char to some spawning lakes. Some char populations are now dropping. It could be a major concern”. Finally, residents identified an increase in the number of sick or diseased wildlife: “We’re seeing stuff now that you never used to see” noted Conservation Officer Allen Niptanatiak. More



Fig. 5 Road and culvert erosion in Kugluktuk, NU, following a storm on 20–21 July 2007.

“skinny”, “bony” and “sick looking” caribou have been seen, as have “diseased”, “sick” and unusually “small” fish, such as char. “Blisters” on some seals have been noted and “infections” have been documented when the animal is cut open, thereby making some traditional food sources suspect for some.

Changes in wildlife dynamics are commonly adapted to by changing the timing and location of harvesting activities as well as the choice of species hunted. The Regional Biologist for the Kitikmeot Region, Matthew Dumond, noted that Kugluktuk residents are in the fortunate position of having access to many traditional food species. Caribou, musk oxen, seals, moose, bears, geese, ducks and fish are all common and if one species is not available chances are that another is. Given the relative abundance of wildlife, sick or diseased wildlife are simply not consumed. At times when traditional foods are not available, people may supplement their diets with food from the local stores. This acts to increase an already existing dependence on store bought food for many individuals. Finally, in situations where some families are unable to secure adequate supplies of country food, the Inuit tradition of sharing is evident in Kugluktuk such that some elders and disabled people are still able to access traditional foods.

Non-climatic exposure-sensitivities and adaptations in Kugluktuk

Climate change constitutes just one of many forces of change experienced by the residents of Kugluktuk; as elder Marion Bolt put it: there has been “lots of change;

it’s not only the weather”. Indeed, for a majority of residents interviewed for this research, the perceived impacts of climate change were deemed less significant than a number of current community-centred concerns. “These are more pressing issues”, noted one respondent. “Our community has [social] issues we need to deal with first”, said another. Climate change should not be dismissed as irrelevant, however. Non-climatic factors can play important roles in a community’s capacity to adapt to climate change and must be considered in an integrated manner (Ford et al. 2006a; Ford et al. 2006b; Smit & Wandel 2006; Pearce, Smit et al. 2010).

Livelihoods

Kugluktuk, like many Inuit communities, has been faced with tremendous social and cultural change since its settlement in the mid-20th century largely as a result of its relatively recent contact with and integration into Western society. The Copper Inuit, from which the Inuit of Kugluktuk descend, were one of the last North American indigenous groups to encounter Europeans (Condon 1996). Initial contact was made by Scottish and American whalers, fur traders and missionaries of varying denominations. At the time of contact, most Inuit were living in semi-nomadic hunting and trapping camps. Subsistence livelihoods were supplemented through trade with whalers during the 19th century and later through fur-trade activities with the establishment of permanent trading posts such as the one at Coppermine (now Kugluktuk) in 1916 (Condon 1996).

Starting in the 1950s, the Canadian federal government began to encourage Northern Aboriginal residents to settle in permanent villages to facilitate medical care, education and social services (Damas 2002). Some residents came in “off the land” as recently as the 1970s. By the 1970s, the semi-permanent hunting–trapping camps had disappeared (McMillan 1988; RCAP 1996; Dorais 2002). Northern settlements, however, had no commercial purpose beyond fur trading and thus opportunities in the wage economy have always been limited (Bone 2000). The fur trade has been in decline since the mid-1980s, with a decrease in the value of some commonly harvested fur species including seal and fox. Nevertheless, Inuit in Kugluktuk continue to engage in subsistence hunting and gathering activities, albeit in a manner that is different from pre-contact times. Inuit now live in fixed settlements and harvesting in close proximity to the community has become the norm, which has put increased pressure on local wildlife populations. Indeed, in Kugluktuk, hunters reported a decline in wildlife in the immediate vicinity of the

hamlet. Consequently, hunters have increasingly been compelled to travel greater distances to find game. This has encouraged greater use of snowmobiles and ATVs, which in turn require fuel and maintenance. Motor-powered boats are used during the ice-free season. More recently, VHF radios, GPS units and satellite phones have become more common for safety, introducing further costs.

While new technologies can offer an effective adaptation strategy for hunters (see also Berkes & Jolly 2001), they also introduce further exposure-sensitivities (Aporta & Higgs 2005; Ford et al. 2007). Given the cost of technology, participation in traditional activities has become prohibitive for those without a sufficient income source, notwithstanding financial subsidies provided by the Nunavut Harvester Support Programme. Opportunities in the wage economy in Kugluktuk are primarily with the local and territorial governments, the local service industry, artisanal activities (e.g., carving, textiles) and sport hunt tourism (e.g., for caribou and musk ox). An additional source of income that is becoming increasingly significant is the regional mining sector. While past mining activity (e.g., exploration camp work, the Lupin gold mine) generated some modest employment, the more recent establishment of four diamond mines in the region (BHP Billiton's Ekati mine, Rio Tinto/Aber's Diavik, De Beers's Snap Lake and Tahera's now closed Jericho), has created unprecedented economic activity and employment (Government of the Northwest Territories 2009). This has been especially true for Inuit given their negotiation of formal agreements—termed Impact and Benefit Agreements (IBAs)—with mineral developers that include, among other things, provisions to ensure employment and the preferential use of Inuit businesses for mine servicing (Galbraith et al. 2007). This has created a new class of residents with greatly increased incomes and associated lifestyles. Hence, as in other northern locales, Kugluktuk is characterized by both new wealth and enduring poverty. In 2006, 22.2% of the hamlet's residents were unemployed (compared to Nunavut and Canadian averages of 15.6% and 7.4%, respectively); more significantly, just 23% of the hamlet's Aboriginal population age 15 or older worked full-time. Even with government transfer payments included (which accounted for just over 18% of Kugluktuk residents' total income in 2006), median after-tax household income for all households in the community in 2005 was 38 827 CAD (Statistics Canada 2006). Given the high cost of living in the north and the high number of children per household, this income level arguably falls below the poverty line.

Demographics

Population dynamics in Kugluktuk similarly point to problematic socio-economic conditions for many households. The Census Aboriginal Profile for Kugluktuk for 2006 (Statistics Canada 2007) indicates that 52% of the total population of Kugluktuk and closer to 56% of the hamlet's Inuit population is under age 25. Further, 89% of the 2006 Inuit population aged five and older lived in Kugluktuk in 2001, indicating relatively low mobility. Lastly, 65% of the houses occupied by Inuit were built before 1991 and the high cost of new construction—the average dwelling was valued at almost 150 000 CAD in 1991—means significant investment is required for new housing. Given that 74% of Inuit live in rented housing and the median monthly rental payment was a mere 100 CAD in 2006, alleviation of the housing shortage is unlikely to occur as a result of market forces.

In light of these socio-economic conditions and especially the high cost of purchased food, the informal economy and subsistence hunting and fishing are important for food security. Beyond its economic value, hunting and sharing of traditional ("country") foods is widely considered one of the core aspects of Inuit ecological and socio-cultural relations (Wenzel 1995; Collings et al. 1998; Pearce, Smit et al. 2010). However, interview data suggest that some youth are less interested in traditional activities and have lost some of their taste for country foods. "The younger generation—they want pop and chips now", noted one respondent. They often don't want to get "bloody and dirty" from hunting and harvesting activities either. A lack of interest in hunting has meant a decline in the associated skills and knowledge including survival skills. "They don't know how to hunt, how to survive. They need to learn", noted elder Jimmy Hanak. Concerns were also expressed over the erosion of traditional knowledge among community youth. The term "traditional knowledge" is most often applied in the context of indigenous populations and, as Usher (2000: 185) states, is "all types of knowledge about the environment derived from the experience and traditions of a particular group of people". In Kugluktuk it is specifically feared that youth have limited knowledge about safe travel conditions and do not have the skills necessary to survive on the land if necessary (e.g., as a result of getting lost or due to extended periods of poor weather). "These days, the kids don't know how to make igloos anymore", noted elder Marion Bolt. Another elder, Lucy Taipana, pointed to the compounding exposure-sensitivity of the erosion of traditional knowledge with the further exposure-sensitivities introduced by climate change: "it's too big a change for young people who are not out on the land, who don't have land skills". An

erosion of traditional knowledge and land skills among younger generation Inuit has been empirically documented by Pearce, Notaina et al. (2010).

The erosion of traditional knowledge is not limited to just land-based skills. Youth generally do not know how to speak Inuinnaqtun competently and consequently cannot converse with elders who are not comfortable with English. This is both caused and compounded by the introduction of Southern education and culture. Young Inuit spend less time with elders than they did in the past, in part, because of mandatory school attendance. Outside school hours, the attractions of satellite television, sports and hanging out with friends compete with time out on the land. Some Inuit respondents expressed frustration that many youth are simply not interested in learning traditional skills. Fewer youth, it was noted, choose to engage in traditional activities such as hunting and fishing, preferring instead to remain in town with friends.

Notwithstanding mandatory school attendance, teachers regularly complain of high absenteeism. More problematically, the drop-out rate in Kugluktuk is high. A local school official estimates that only one-quarter of all Kugluktuk youth who start elementary school go on to graduate from high school, which explains and perpetuates the fact that just half of the current resident population of Kugluktuk has attained a high school education. The reasons for this situation are many and complicated, including incidences of learning disabilities and Fetal Alcohol Spectrum Disorder and more common challenges like a lack of readiness for schooling among young children (Schofield 1998).

Given new wealth for some, lasting poverty for others, overcrowding in homes, the erosion of traditional knowledge and low education levels, it is perhaps not surprising that Kugluktuk residents report high rates of crime, substance abuse and suicide. Residents often complained of criminal activities in town such as spousal abuse, vandalism, alcohol bootlegging and drug trafficking. Crimes are often alcohol and drug related and alcoholism appears to have increased in recent years. One respondent noted that "It wasn't common to see a drunkard on the road when I grew up", whereas now it is. A local police officer identified Kugluktuk as having the highest youth crime rate in Nunavut and an above-average adult crime rate as compared to the rest of the territory. Suicide, especially youth suicide, is also a major concern for community members. For example, over two and a half months in the summer of 2007, when fieldwork was completed for this paper, three Kugluktuk youth took their lives; these came on top of five previous suicides in 2007. These numbers are consistent with broader trends in the territory, as evidenced in Nunavut's suicide rate of

87.4 per 100 000 people during 2000–05. The Canadian average suicide rate, by contrast, is only 11.7 per 100 000 people for the same time period (Statistics Canada 2010). Tester and McNicoll (2004) have called Inuit suicide the most significant mental health issue in Nunavut and argue that low Inuit self-esteem rooted in a history of colonialism, paternalism and historical events is a contributing factor.

The community has taken measures to address some of these social challenges including the introduction of a youth curfew, stay in school programmes and the establishment of an alcohol committee in 2007. The curfew requires that youth be home by 22:00 on week-nights and 02:00 on weekends but is considered largely ineffective (George 2007a). Furthermore, many youth would simply be returning to unsafe homes where alcohol and abuse are prevalent (George 2007a). The Kugluktuk Grizzlies programme is designed to keep youth in school and promote healthy lifestyles. The programme operates on the principle that, in order to play on high school sports teams (Grizzlies teams) one must have 80% attendance at school and stay out of trouble with the law. Grizzlies members often get to participate in regional, national and international tournaments, are entered into draws for prizes and may be nominated for awards based on their competencies. In 2007, the Grizzlies had 83 student members. The programme has been lauded in the community and across Nunavut (e.g., George 2007b). The alcohol education committee is designed to address alcohol-related problems including suicide, bootlegging and violence (CBC 2007). Guidelines are still being established, though alcohol education committees frequently function on an "alcohol by permit" model where all alcohol is ordered from an out-of-community distribution site. Some progress has also been made towards rectifying the erosion of traditional knowledge and language among youth. Traditional knowledge camps have been organized to bring together elders and youth for extended periods of time out on the land in order to transfer knowledge and skills, aspects of traditional knowledge are being taught in Kugluktuk's schools, community elders are asked to come into classes and teach traditional knowledge-related lessons and the Government of Nunavut recently appointed Inuit languages (including Inuinnaqtun) as the primary languages to be taught in junior grades in the territory.

Governance

Management of the many social challenges facing the community is not limited to the community scale alone.

The signing of the Nunavut Land Claims Agreement and the associated establishment of the Territory of Nunavut in 1999 has provided Nunavummiut with more decision-making power over issues that affect them and has helped shape a government reflective of their culture, traditions and goals. Through their government, Nunavut residents have greater control over education, health, social services and wildlife management. For example, in July 2007, the Government of Nunavut released a new suicide prevention strategy, which aims to curb the territory's alarmingly high suicide rate. The government also helps stimulate the regional economy, creating government jobs as well as spin-off jobs in the private sector. Furthermore, the Nunavut government receives a share of federal government royalties from oil, gas and mineral development on Crown lands and retains the right to negotiate IBAs with industry for non-renewable resource developments. These higher scale institutional strategies cannot address all social ills in communities like Kugluktuk but they constitute a significant and important trend towards increased self-governance and heightened administrative capacity in the region.

Considerations of the future vulnerability of Kugluktuk to climate change

As detailed previously, residents of Kugluktuk are currently exposed to a number of environmental, social, economic and political exposure-sensitivities. In several instances, the perceived threat of climate change was over-shadowed by persistent social issues such as crime, loss of language and land skills and youth suicide. However, these non-climatic related factors influence capacity to adapt to climate change exposure-sensitivities and are thus important components of vulnerability. For example, some respondents have adapted to changing ice conditions by adjusting the timing and modes of travel on the land. The ability to adapt is dependent on the ability of the respondent to be flexible in the timing of harvesting, access to alternative modes of transportation (e.g., boat, ATV, snowmobile) and having the knowledge and skills necessary to change harvesting locations and techniques. Other climate-related vulnerabilities continue to present challenges for harvesters. Erratic weather conditions and thinning ice are creating circumstances whereby those travelling on the land are exposed to greater exposure-sensitivities. Another obvious climate-related vulnerability derives from community infrastructure that is not well adapted to changing environmental conditions, especially permafrost melt.

Drawing on this picture of current vulnerability and consistent with the vulnerability approach, Kugluktuk's

future vulnerability to climate change can be considered by identifying: (1) relevant future climatic exposure-sensitivities, and (2) the community's future adaptive capacity. Securing evidence of the former is made easier with the use of region-specific climate forecasts; however, even climate data projections include some uncertainty, which makes their use less than straightforward. Furthermore, securing evidence of the latter can be especially challenging considering the various uncertainties surrounding community sensitivity to multiple exposure-sensitivities. Though research has identified determinants of adaptive capacity in Arctic communities (e.g., Ford et al. 2010), it is beyond the scope of this paper to do so for Kugluktuk for the purpose of developing reasonable projections of the hamlet's future adaptive capacity. Hence, in the following, potentially relevant climatic exposure-sensitivities are identified as drawn from regional climate forecasts and likely impacts and adaptations are considered in light of existing adaptive capacity as well as under alternative future socio-economic situations. In addition, necessary adaptations given anticipated climatic exposure-sensitivities are identified throughout and a broader suggestion for addressing multiple exposure-sensitivities in the future is offered.

The Intergovernmental Panel on Climate Change has summarized climate projections for broad regions (Christensen et al. 2007). Unfortunately, climate projections for the Canadian Arctic only give general seasonal trends in temperature, precipitation and ice dynamics and offer limited insight to critical issues like extreme events and future wind dynamics. (Kattsov & Kallen 2005). Median climate projections using the most common A1B (rapid economic growth, global population peaking at nine billion by 2050, quick spread of technologies, emphasis on balanced energy sources) scenarios for the Kugluktuk region, the 2080 to 2099 period will experience over four degrees of warming as compared to norms of the latter part of the last century. These projections are approximately double the average anticipated global warming over the same period. The greatest warming in Arctic North America is expected during the winter months of January to February, followed by fall and early winter (September to November). The fall and winter temperature regimes under these scenarios are slightly warmer than late 20th century average conditions for Yellowknife, which is almost 600 km further south and south of the tree line. Furthermore, models predict that, on average, the Arctic region will see precipitation increase by 22% over the whole year, with the greatest increase in the fall and winter (26% and 29%, respectively).

Ice dynamics are related to a host of complex variables including temperature, snow cover, wind, heat exchange at leads and polynyas and Arctic circulation. In particular, sea-ice thickness, which is widely viewed as a critical issue, is inadequately understood (Walsh et al. 2005; Christensen et al. 2007). That said, as detailed in the *Arctic climate impact assessment* report (Symon et al. 2005), Arctic sea-ice extent is expected to decrease in the short, medium and long-term and the decrease in summer sea-ice extent is expected to be greater than that in winter (Walsh et al. 2005). In the summer of 2007, Arctic sea ice declined to unprecedented low extents; ice extent in September 2007 was estimated to be 50% lower than conditions in the 1950s to the 1970s (Stroeve et al. 2008). Stroeve et al. (2007) have argued that existing climate change models used by the Intergovernmental Panel on Climate Change actually under-represent observed trends and are rather conservative forecasts of Arctic sea-ice decline. Given the conservative model results and the unprecedented events in 2007, Stroeve et al. (2008) have predicted that a seasonally ice-free Arctic Ocean might be realized as soon as 2030. This predication is supported by the Arctic Monitoring and Assessment Programme's latest report, *Snow, water, ice and permafrost in the Arctic* (AMAP 2011). Indeed, this report predicts that the Arctic Ocean will be ice-free in summers within 30–40 years (AMAP 2011).

Similarly, warming trends will continue to contribute to permafrost degradation and associated infrastructure problems. Although Kugluktuk is located on the Canadian Shield, which has a relatively lower concentration of ground ice as compared to the Mackenzie Delta to the west, an increase in the active permafrost layer will mean continued difficulties for community infrastructure and travel routes. Extreme precipitation events like that experienced in July 2007 are projected to become more frequent and their intensity will likely increase (Kattsov & Kallen 2005). This will likely mean that road and infrastructure damage will be repeated unless planning and engineering is fundamentally changed. Increases in winter precipitation may increase snow removal costs in Arctic communities (Walsh et al. 2005) and deep snows could be problematic for travel by snowmobile.

Sea-level rise is expected to affect coastal zones in the region. Most sea-level rise models included in the *Arctic climate impact assessment* (Symon et al. 2005) expect sea-level changes of 0.2 m (and up to 0.6 m) between 2000 and 2100 in the Canadian Arctic Archipelago (Walsh et al. 2005). Coastal regions are vulnerable to erosion during the ice-free period if wind speeds exceed 10 m/s or 36 km/hr (Walsh et al. 2005). During the latter part of the 20th century, average wind speeds for the open-water months

in Kugluktuk were just over 14 km/hr and periods with sustained winds above 36 km/hr, while infrequent, have certainly occurred (Environment Canada 2010). Given expected sea level rise and coastal permafrost degradation, increased coastal erosion can be expected even if winds were to remain unchanged.

It is expected that wildlife in the Kugluktuk region will continue to be impacted by climate change. Changes in the range, health and availability of many marine, freshwater and terrestrial wildlife species are expected to occur throughout the Arctic with climate change, with some species being particularly affected. A decline in certain species could also have cascading effects for the species that hunt them as well as species that scavenge on them (Symon et al. 2005). Changes in the range and availability of wildlife would force community residents to adapt their harvesting strategies accordingly. The timing and location of harvest, methods used and species sought after are just some examples of where adaptations may need to occur. Furthermore, policy responses are needed. The further development of policies that focus on supporting and promoting subsistence harvesting, wildlife management and harvester support will help reduce community and harvester vulnerability to changing climatic conditions in Nunavut (Ford et al. 2007).

In sum, it is likely that current climate-related exposure-sensitivities in the Kugluktuk area will become more pronounced in the future. The number of people exposed to climate change effects will likely also increase as Inuit community populations in Canada continue to grow rapidly. For those future exposure-sensitivities related to travel on sea ice and open water and for hazards associated with the unpredictability of conditions, future technologies related to weather prediction and communications will undoubtedly augment adaptive capacity; however, future behavioural adaptations will also be necessary such as “waiting it out”. With respect to infrastructure, effective adaptation will require a shift from a reactive “repair the damage” strategy to one based on longer-term engineering solutions. For example, coastal erosion is primarily a problem if critical infrastructure is located immediately adjacent to the shoreline; by relocating this infrastructure to higher elevations, this problem could be alleviated somewhat. Similarly, road construction can be engineered to allow for greater runoff from storm events through measures such as larger culverts. However, planning and engineering solutions require time and resources, which in turn requires prioritizing expected changes based on uncertain model outputs.

While the above identified adaptations to future climate-related exposure-sensitivities appear feasible, this simple depiction of the future vulnerability of Kugluktuk to climate change is easily muddled when one recognizes: (1) that some individuals will be more vulnerable to climate change than others and (2) the implications of even modest shifts in the community's social, political and/or economic conditions. With respect to the former, travelling on the land in harsh conditions offers a good example. It is evident that those who venture out on the land need certain skills and traditional knowledge to manage extreme or just altered environmental conditions. Hence, youth who ride snowmobiles across unsafe ice and hunters without the skills necessary to endure severe winter storms are more vulnerable to climate change. Variability in individual levels of vulnerability to climate change can also be driven by other personal circumstances. For example, a lack of financial resources may mean that individuals are unable to purchase beneficial technologies such as a GPS or satellite phone or pay for necessary repairs to their home in the event of permafrost or storm damage.

With respect to the influence of changes in social, political and/or economic conditions on the future vulnerability of Kugluktuk to climate change, simple scenarios can serve to reveal varied possible outcomes. For example, increased investment in northern mineral exploration and development as a result of sustained commodity prices, coupled with longer ice and snow-free seasons and the opening of the North-west Passage, could greatly increase employment opportunities for, and the wealth of, certain residents of Kugluktuk. While this constitutes an opportunity for some, it may also generate social ills such as alcoholism, augment class disparities and further lessen interest in traditional knowledge and lifestyles. In turn, this might result in seemingly simple adaptations to changing climatic conditions becoming highly improbable or even impossible. Potential environmental repercussions and impacts to wildlife from mining could also further hinder harvesting-related adaptive responses. Alternatively, this increased industrial development scenario could entail the negotiation of progressive and effective IBAs that offer communities like Kugluktuk tangible benefits such as improved infrastructure and education resources and enable support for traditional subsistence activities and the transmission of traditional knowledge and languages from elders to youth. Under this scenario, community adaptive capacity to manage future climatic or other changes could instead be enhanced (Bradshaw et al. 2009).

Rather than speculate on the likelihood of these alternative socio-economic futures, it may be more

productive to focus broadly on what is needed to ensure sufficient adaptive capacity at the community scale. One approach, which has increasingly been advanced (e.g., Ford et al. 2010; Pearce, Smit et al. 2010), suggests that effective adaptation to future climate change necessarily requires that persistent socio-economic issues be addressed and that vulnerable groups be specifically targeted. Another arguably more pragmatic approach calls for the integration of efforts to manage climate change with those directed at socio-economic issues; that is, climate change adaptation and capacity-building should be mainstreamed into social policy and socio-economic development strategies should consider the potential impacts of climate change.

Conclusions

Climate change in the Canadian Arctic is being, and will be, managed by communities that are already experiencing social, political, economic and other environmental changes. These changes are occurring as a result of, for example, a boom in mineral extraction, the increasing penetration of a Southern culture, ongoing self-government processes and emerging health concerns. While there is general agreement that these multiple exposure-sensitivities are likely to pose significant challenges for Northern communities, the nature of these exposure-sensitivities, their interactive effects and the most effective means of managing them are, as yet, poorly understood. Hence, there is a need to understand vulnerability to climate change in the context of multiple exposure-sensitivities at the community level. This paper has sought to respond to this perceived knowledge need based on an application of the vulnerability approach to the community of Kugluktuk in Nunavut, Canada. This approach enabled the identification of both current climatic and non-climatic exposure-sensitivities along with their associated contemporary adaptation strategies; from this assessment of current vulnerability, Kugluktuk's future vulnerability to climatic change in the context of multiple exposure-sensitivities was considered.

There is widespread recognition in Kugluktuk that climatic conditions are changing and as a result generating new challenges. For example, changing ice conditions are making travel on ice more precarious and sometimes infeasible and unusual weather events such as freezing rain have affected travel and hunting. In response to many of these challenges, residents of Kugluktuk have developed adaptive strategies such as altering travel routes or the timing of travel and ensuring heightened preparedness while on the land by using weather reports and GPS. For some other climate-related challenges,

adaptation is less evident and some current vulnerabilities exist, most notably with respect to risky travel over thin ice or in unpredictable weather conditions and community infrastructure that is sensitive to permafrost melt and extreme weather. Notwithstanding these lingering vulnerabilities, many community members view climate change as a minor concern, outweighed by social issues such as overcrowding of housing, the erosion of traditional knowledge and youth suicide. While some may, in light of these persistent social challenges, dismiss climate change as a real concern, this conceptualization of life in Kugluktuk may result in lost opportunities to address social issues via climate change adaptation planning.

Community concerns and exposure-sensitivities cannot necessarily be ranked and the less significant ones ignored; the lives of residents in Kugluktuk are marked by multiple concerns and exposure-sensitivities. Hence, a more accurate conceptualization recognizes that the community's many social issues inevitably constrain efforts to manage a variety of externally generated exposure-sensitivities including climate-related ones. This view lends support to the argument that effective adaptation to climate change requires attention to issues including and in addition to the physical impacts of future change. Pressing social issues in communities like Kugluktuk will fundamentally influence the adaptive capacity of the community. In effect, climate change adaptation planning and efforts to address current social issues in Northern communities are intertwined and might both benefit from integrated, cooperative approaches.

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