Chapter 3
Vulnerability and Adaptation in Two Communities in the Inuvialuit Settlement Region

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Abstract This chapter compares the Inuvialuit communities of Ulukhaktok and Tuktoyaktuk in the western Canadian Arctic according to the CAVIAR analytical framework. The comparison highlights examples of similarities and differences in exposure-sensitivities and adaptations related to subsistence harvesting and community infrastructure. Subsistence hunting, fishing and trapping on the land and sea ice continue to be valued activities for Inuit in Ulukhaktok and Tuktoyaktuk. In both communities, however, changes in seasonal patterns, sea ice, and weather variability have affected the health and availability of some important wildlife species and have exacerbated risks associated with hunting and travel. Infrastructure in Tuktoyaktuk is highly susceptible to damage due to degradation of permafrost and coastal erosion. The shorelines of the community are prone to erosion, particularly during strong storm events that have damaged buildings and roads in the past. A prominent difference in the capacity of these communities to deal with climate-related exposure-sensitivities is the diversity of their economies and extent to which they rely on subsistence harvesting. This comparison provides insight into the localized nature of vulnerabilities, and policies to support adaptation.

Keywords Subsistence harvesting · Infrastructure · Inuvialuit · Tuktoyaktuk · Ulukhaktok

3.1 Introduction

Inuit in the Canadian Arctic have experienced rapid social, economic, and political changes during the last half of the twentieth century (Condon 1987; Damas 2002; Hamilton 1994; Irwin 1989). These changes, including moving

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into permanent settlements, the introduction of new technologies (e.g. mechanized transportation), resource development, and land settlement agreements, have transformed Inuit lives and livelihoods. Additionally, Inuit are increasingly faced with challenges associated with climate change (e.g. Ford et al. 2008; Huntington et al. 2007; Pearce et al. 2010).

Some of the most dramatic changes in climatic conditions in the Arctic have been documented in the Inuvialuit Settlement Region (ISR) in the western Canadian Arctic. These changes are affecting communities, and scientists project that further changes in temperature, wind and precipitation will lead to greater variability in timing of seasonal events, increased permafrost degradation and erosion, decreased sea ice cover, and implications for the health and availability of some wildlife species important for subsistence (ACIA 2005; Anisimov et al. 2007; Cohen 1997; Furgal and Prowse 2008; GNWT 2008). Given the effects of current climatic changes and predicted future impacts, the development of adaptation responses has been identified as a priority by the scientific community (Ford et al. 2010; Furgal and Prowse 2008; Huntington et al. 2007; Pearce et al. 2010), Inuit Organizations (Nickels et al. 2006), and the Government of the Northwest Territories (GNWT 2008). This chapter outlines the nature of vulnerability to climate change, in the context of other societal changes, in two Inuvialuit communities, Tuktoyaktuk and Ulukhaktok. The chapter also documents current adaptive strategies being employed to deal with climate risks and discusses opportunities to enhance adaptive capacity to deal with expected future changes.

3.2 Study Locations

Case studies were conducted in the communities of Tuktoyaktuk and Ulukhaktok, two of the six communities in the ISR. Both communities are located on the coast of the Beaufort Sea, with Tuktoyaktuk situated on a peninsula east of the Mackenzie delta and Ulukhaktok on the western side of Victoria Island (Fig. 3.1).

While both communities are accessible via air transport year-round and boat during summer months, Tuktoyaktuk is also connected to Inuvik and the Dempster highway via an ice road from December until April. Table 3.1 provides an overview of the demographic characteristics of the communities. Both communities have young, growing populations that are primarily Inuit. While some residents speak Inuvialuktun or Inuinnaqtun, English is commonly used in both communities.

Similar to most communities in the Canadian Arctic, Tuktoyaktuk and Ulukhaktok have mixed economies composed of waged employment and subsistence harvesting (Table 3.2). Financial income is largely based on government and municipal services, seasonal employment (e.g. sport hunt guiding and tourism), arts and crafts, social transfer payments, and occasional employment

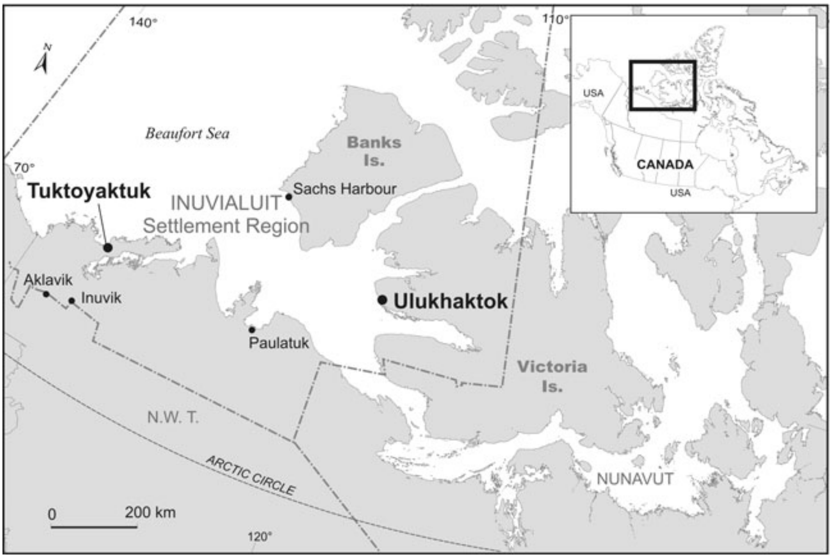

Fig. 3.1 Location of Tuktoyaktuk and Ulukhaktok in the Inuvialuit Settlement Region, NWT, Canada

in resource-extraction industries (Condon 1987; Pearce et al. 2010). Despite rapid socio-economic and lifestyle changes over the past half century, subsistence hunting, fishing and trapping on the land and sea ice continue to be valued activities for Inuit. In Tuktoyaktuk 57% of community members and in Ulukhaktok 76% of community members participate in hunting and fishing (Bureau of Statistics GNWT 2008). Harvesting and the consumption of country foods (locally harvested fish and wildlife) is a fundamental aspect of Inuit culture and are important to many families for food security (Collings et al. 1998; Pearce et al. 2010; Wein et al. 1996) (Table 3.2).

Table 3.1 Demographic characteristics of Tuktoyaktuk and Ulukhaktok. All figures based on 2006 census data

	Tuktoyaktuk	Ulukhaktok
Population	950	400
Proportion of population that is aboriginal	97%	99%
Languages spoken	English, Inuvialuktun	English, Inuvialuktun, Inuinnaqtun
Age Distribution		
Population 0–19 years of age	39%	44%
Population 20–39 years of age	29%	28%
Population 40–59 years of age	25%	22%
Population >60 years of age	7%	6%

Table 3.2 Species harvested and sources of employment in Tuktoyaktuk and Ulukhaktok

	Tuktoyaktuk	Ulukhaktok
Employment sources	Government, health services, social services, education, oil and gas industry, shipping, retail, construction, outfitters	Government, health services, social services, education, retail, mineral exploration, outfitters
Proportion of community participating in wildlife harvesting	57%	76%
Proportion of households relying on country foods as primary meat source	50%	46%
Species commonly harvested	Barren-ground caribou, beluga whales, Arctic cisco, broad whitefish, lake whitefish, inconnu, lake trout, Pacific herring, lesser snow geese, white-fronted geese, brant	Arctic char, ringed seal, bearded seal, lake trout, Peary Caribou, Dolphin-Union caribou, musk-ox, King Eider ducks, snow geese

While the means of harvesting are similar in Tuktoyaktuk and Ulukhaktok, the species available in each community differ. For example, beluga whales, Arctic cisco, and Pacific herring are commonly harvested in Tuktoyaktuk but not in Ulukhaktok. Conversely, Arctic char and King Eider ducks are commonly harvested in Ulukhaktok but not in Tuktoyaktuk. Musk-ox and seals are available in the areas around both communities but are harvested more commonly in Ulukhaktok.

3.3 Study Approach and Methods

Research was conducted in collaboration with community members in Tuktoyaktuk and Ulukhaktok and was structured using a vulnerability approach described by Ford and Smit (2004), Smit et al. (2008) and outlined in Chapter 1 of this book. This approach to vulnerability assessment is broadly consistent with the frameworks of Turner et al. (2003), Fussel (2007), Keskitalo (2008), and others. The vulnerability approach conceptualizes vulnerability to climate change as a function of exposure-sensitivity and adaptive capacity, current and future (see Chapter 1). Vulnerability is assessed at a local level and is conditioned by a synergy of social, economic, political, cultural and climatic conditions and processes, operating at multiple scales over time and space (Ford et al. 2008). Identifying climate-related conditions that are relevant to people, how they affect livelihoods, the adaptive strategies they employ, and how climate change might affect future activities, requires engaging local people in the research process (Pearce et al. 2010; Smit and Wandel 2006; Tyler et al. 2007). In both case studies, community members were involved in research design, development, and application – as research assistants, interpreters, cultural guides, and informants. The methods used to involve community members in the research are described in detail in Pearce et al. (2009).

In Ulukhaktok, 62 primary and 14 follow-up interviews were conducted with a cross-section of community members, and 40 interviews were conducted in Tuktoyaktuk. A purposive sampling strategy was used to recruit a sufficient representation of different groups in the community. A snowball sampling method was then used in which local research assistants helped identify people within identified groups willing to participate in the research, who then led to others who were willing to participate (Andrachuk 2008; Pearce et al. 2010). The interviews were complemented with informal meetings and numerous trips on the land with community members to learn first-hand how people interact with the local environment and to better understand how climatic changes are affecting them. Interviews were semi-structured and questions were open-ended to minimize interview bias or prompting and to allow respondents to describe their experiences and observations in their own terms (Ferguson and Messier 1997; Fienup-Riordan 1999). Semi-structured interviews are a standard method for collecting data in an open-ended format and have been widely used in northern research (Ford et al. 2006a, b; Noongwook et al. 2007; Huntington 1998; Riedlinger and Berkes 2001). Interviews, and subsequent analysis, were guided by the intent to identify current exposure-sensitivities, current adaptive strategies, future exposure-sensitivities and future adaptive capacity.

Collaboration with researchers in the climate science community and an analysis of secondary sources of information including climate records, books, published papers, and government reports was undertaken, and the information gathered was incorporated as appropriate in the assessment of vulnerabilities. After the initial periods of data collection, five subsequent visits were made to Ulukhaktok and one to Tuktoyaktuk to evaluate and review the results with community members, disseminate findings, and conduct other related research.

3.4 Current Exposure-Sensitivities and Adaptive Strategies

This chapter describes changing climatic conditions together with changing socio-economic conditions, with a focus on the ways that they are effecting *harvesting* and *infrastructure* in Tuktoyaktuk and Ulukhaktok. There is evidence of increased risks associated with travel on the land and sea ice, constrained travel access to hunting areas, compromised food security and health status of wildlife, and damage to municipal infrastructure and building foundations in these communities (e.g. Andrachuk 2008; Duerden and Beasley 2006; Pearce et al. 2010; Solomon 2005) (Table 3.3).

Table 3.3 Current exposure-sensitivities related to harvesting and infrastructure in Tuktoyaktuk (T) and Ulukhaktok (U)

	Exposure-sensitivities	Description
Harvesting	***Health and safety*** • Compromised travel routes to harvesting grounds • Increased travel risks	• Less predictable weather makes it difficult to know when conditions are suitable for travel (T,U) • Harvesters have become stranded, injured and/or have lost or damaged equipment due to changing sea ice conditions, rapid seasonal transitions (e.g. spring melt), and increased storminess (U) • Snow machines become stuck in melting snow (U) • High rivers block access to spring hunting and fishing grounds (U) • Less sea ice cover and thinner ice reduces access to hunting grounds (U)
	Food security • Health of wildlife and quality of meat • Availability of wildlife	• Fewer caribou have resulted in hunting regulations (T,U) • Poor quality of ringed seals = less country food and dog food (U) • Fish spoil faster in nets due to warmer water temperatures (U,T) • Fewer migratory fish and softer flesh that is more prone to spoiling (T)
Infrastructure	***Buildings and transportation*** • Permafrost degradation • Coastal erosion • Ice cover on Mackenzie River and Beaufort Sea	• Warmer summer temperatures cause increased permafrost degradation (T,U) • Building foundations are susceptible to permafrost heaving and slippage (T) • Coastal erosion putting several buildings at risk during strong storms (T) • Timing of supply barge affected by summer ice conditions (U)
	Municipal services • Damage to sewage lagoons	• Strong storm events cause flooding and inundate lagoons (T,U)

3.4.1 Harvesting: Current Exposure-Sensitivities

The dependence of Inuit in both communities on fish and wildlife for cultural and social activities, subsistence and employment makes them susceptible to climatic changes that affect hunting and fishing. In recent years community members and scientists have documented changes in temperature, seasonal patterns, weather variability, ice conditions (sea ice and river ice), wind dynamics and snowfall with implications for travel safety, travel routes, and species health. In Ulukhaktok changing sea ice conditions have affected travel routes on the sea ice to seal, duck, and polar bear hunting grounds, and earlier and more rapid spring melts have affected travel inland by all-terrain vehicles

(ATV) to spring fishing and hunting areas (Pearce et al. 2010). Less predictable weather and increased occurrence of extreme storms is also making it more difficult for harvesters to know when conditions are suitable for travel.

Travelling and harvesting on the land and sea ice is inherently dangerous but in recent years climatic changes have altered and, in some cases, increased the magnitude and frequency of hazard events (Pearce et al. 2010). In some cases harvesters from Ulukhaktok have become stranded, injured and/or have lost or damaged equipment due to changing conditions. Community members in Tuktoyaktuk have not reported the same disruption to winter travel routes, although they have reported that they are less certain about weather and ice conditions when harvesting animals that are found at greater distances from the community, such as polar bears or musk-ox (Andrachuk 2008). As a result of settlement in communities and changes in socio-economic relationships, most community members now spend the majority of their time in the community, not on the land where they could observe the development of environmental conditions. This is diminishing some community members' ability to predict weather and ice conditions and increasing travel risks.

In both communities a decline in caribou populations has resulted in hunting regulations and a decline in the number of harvesters obtaining caribou. Caribou is an important and preferred source of meat in Ulukhaktok but beginning in the late 1970s, there has been a dramatic decline in the Peary caribou (*Rangifer tarandus pearyi*) population on Victoria Island (Ulukhaktok harvesting area) (Pearce et al. 2010). A potential explanation for this dramatic population decline are the freeze and thaw events that have occurred during the migration period for caribou, hindering travel and making it more difficult for them to forage for food (Barry et al. 2007). The Bluenose-west and Cape Bathurst caribou herds (*Rangifer tarandus groenlandicus*) near Tuktoyaktuk have had similar declines within the last decade (Environment and Natural Resources 2006; Nagy and Johnson 2006). Some hunters contest these conclusions and believe that the herds have shifted their migratory routes, as they have in the past. Caribou is also a preferred meat in Tuktoyaktuk and provided a reliable source of income for many families in the community until moratoriums on sport hunting were put in place in 2007.

3.4.2 Harvesting: Current Adaptive Strategies

Inuit have a long history of adapting to changing conditions. In both Ulukhaktok and Tuktoyaktuk, Inuit adaptability is evident in the strategies being employed to deal with current climate related exposure-sensitivities (Table 3.4), but the feasibility of many adaptive strategies depend on non-climatic factors. Examples of adaptive actions being undertaken in Ulukhaktok to deal with changing conditions that affect harvesting include: the substitution of store

Table 3.4 Current adaptive strategies employed to deal with climate related risks to harvesting

Adaptive strategies	Constraints
Health and safety	
• Travel with extra supplies (i.e. gas, fuel, food, etc.) • Travel with VHF radios, GPS and/or satellite phone • Use alternative modes of transportation and travel via alternative travel routes in response to changing trail conditions • Travel in groups and leave itineraries with people in the community • Wait for improved conditions • Harvester assistance programs (e.g. IHAP) to provide harvesters with economic resources • Read environmental signs and weather forecasts before traveling	• High costs (i.e. gas, fuel, communication and transportation equipment) • Inability to access capital resources necessary to purchase harvesting equipment (i.e. boat, snowmobile, ATV) • Substance abuse saps material resources and impairs decision-making • Changing levels of traditional ecological knowledge and land skills • Employment limits the timing and duration of harvesting activities
Food security	
• Substitute less accessible species with those more locally available • Eat more store-bought foods • Inter and intra community trade of country foods • Empty fish from nets more frequently to avoid spoilage in warmer waters • Implement conservation plans and wildlife monitoring programs	• Preference for certain species which may become less readily available (i.e. caribou) • Inability to harvest country foods has social, cultural and health implications

foods for traditional foods when hunting areas are not accessible, sharing country foods, using alternative modes of transportation (e.g. ATVs instead of snow machines to travel inland in the spring) and routes to hunting grounds, switching species of wildlife harvested (e.g. hunting musk-ox instead of caribou when caribou are less abundant or farther from the community), and taking extra precautions and supplies when traveling on the land (Pearce et al. 2010). For the most part, these adaptive strategies can be described as reactive and autonomous to the individual or household.

Adaptive actions in Tuktoyaktuk have also included supplementing the decline of one species with another that is more accessible (e.g. harvesting more fish and musk-ox when caribou numbers are low), consumption of more store foods, purchasing traditional foods from full-time harvesters, and avoiding travel during adverse weather conditions. In both communities, adaptations have been reactive and little long-term adaptation planning has been undertaken to enhance adaptive capacity to deal with projected future changes. Access to capital resources, a key for many adaptive strategies, is largely influenced by the ability of individuals or families to secure consistent employment and is manifest through their ability to purchase boats, ATVs, snow machines, and firearms and ammunition.

3.4.3 Infrastructure: Current Exposure-Sensitivities

Infrastructure in Tuktoyaktuk is highly susceptible to damage due to permafrost degradation and coastal erosion. The mainland coast of the Beaufort Sea is characteristically prone to erosion, with average retreat rates of one meter per year (Carmack and Macdonald 2002). The shorelines of the community itself (prior to shoreline protection measures, which were initiated in the 1970s) are known to have eroded on average one to two meters per year, but erosion of several meters has occurred during individual storms (Couture et al. 2002; Hamlet of Tuktoyaktuk 1984; Manson et al. 2005; Reimnitz and Maurer 1979; Solomon and Hart 2000; Solomon et al. 1993). It is generally thought that since sea ice provides protection for shorelines by suppressing the development of waves, longer open water seasons are enabling greater rates of erosion (Carmack and Macdonald 2002; Manson et al. 2005; Manson and Solomon 2007; Rachold and Cherkashov 2003). Average daily energy acting upon shorelines has a relatively small impact on shorelines compared to strong storm events can cause considerable change in relatively short periods of time with winds blowing from the northwest (Atkinson 2005; Manson and Solomon 2007). Such events of rapid coastal retreat tend to occur in the late August and September in Tuktoyaktuk when strong storm events are more frequent (Couture et al. 2002; Johnson et al. 2003; Manson et al. 2005; Reimnitz and Maurer 1979). Unlike in Tuktoyaktuk, infrastructure in Ulukhaktok is situated on stable land with low ice concentrations in the permafrost; nonetheless, warmer temperatures and melting permafrost has caused some damage to building foundations.

3.4.4 Infrastructure: Current Adaptive Strategies

Adaptations to infrastructure exposure-sensitivities in Tuktoyaktuk have been ongoing since the mid-1970s and have focused on shoreline protection measures (Table 3.5). The community, with support from territorial and federal governments, has attempted to slow rates of erosion through a variety of means, including sand bags, concrete slabs and boulders (Johnson et al. 2003). The concrete slabs and boulders have been the most effective and the community has now covered the most erosion-prone stretches of shoreline. These shoreline protection strategies are limited because the local government does not have the financial means to undertake these projects on its own. Shoreline protection has also been limited by a lack of rock and other materials in the community's vicinity. Boulders have been trucked to Tuktoyaktuk via an ice road during winter months and placed on the shoreline once ice recedes. As of 2009, an all-weather road that leads

Table 3.5 Current adaptive strategies employed to deal with climate related risks to infrastructure

Adaptive strategies	Constraints
Building foundations and municipal services	
• Install shoreline protection to prevent or slow erosion (T) • Relocate buildings at imminent risk from damage due to coastal erosion (T)	• Destruction of shoreline protection infrastructure as a result of wash-over, altered sedimentation, and erosion of tundra anchoring points (T) • High cost of climate proofing
Roads and transportation	
• Greater insulation for roads, airstrips, and buildings to protect against permafrost thaw	• Local availability and cost of aggregates

inland to a gravel source has commenced construction and will alleviate some of the logistical constraints. Another adaptation strategy employed by the community has been to relocate or remove buildings that have been put at imminent risk due to coastal erosion. These actions have only occurred in a handful of instances because community planning has focused on shoreline protection.

3.5 Future Exposure-Sensitivities and Adaptive Capacity

In accordance with the CAVIAR framework, current exposure-sensitivities in Ulukhaktok and Tuktoyaktuk were considered relative to future climate change and socio-economic projections to provide insights on potential future vulnerabilities. The future exposure-sensitivities presented here are intended to illustrate a range of possible impacts and stresses that may be experienced in these communities. Projections for warming in the Arctic vary under different climate change scenarios but there is general agreement that the ISR is likely to be facing warmer summer temperatures, less extreme cold during winters, increased precipitation, increased storm frequency, reduced sea ice thickness and cover, and greater variability of weather and timing of seasonal events such as spring sea ice break-up (Carmack and Macdonald 2002; Christensen et al. 2007; Hinzman et al. 2005; Kattsov and Kallen 2005; Lemke et al. 2007; Nuttall et al. 2005). These projected changes are considered here in light of current exposure-sensitivities, with emphasis placed on their implications for people.

3.5.1 Harvesting: Future Exposure-Sensitivities

Climate change is affecting sea ice thickness and dynamics, precipitation, and other factors that are important for the health, breeding success and movement of wildlife (Table 3.6). Several researchers have suggested that alterations to the timing of these conditions and seasonal events (e.g. timing of sea ice

Table 3.6 Future climate change projections and possible future exposure-sensitivities related to harvesting

Future climate change projection	Future exposure-sensitivities
Health and safety	
• Increased frequency of extreme climate events (Kattsov and Kallen 2005) • Reduction in sea ice cover and volume (Barber et al. 2008; Serreze et al. 2007; Sou and Flato 2009) • Later freeze-up and earlier break-up of lake and river ice (Walsh et al. 2005) • Increased precipitation in the spring (Kattsov and Kallen 2005)	• Exacerbate risks associated with travel on the land and sea ice. • Compromise travel routes on the sea ice to hunting areas. • Increased risk of becoming stuck-stranded in melting conditions • Compromised travel routes to spring hunting areas (e.g. fishing at inland lakes) • Less time spent on the land with implications for social well-being.
Food security	
• Decline in polar bear population and health (Derocher et al. 2004; Stirling and Parkinson 2006) • Loss of polar bear habitat (sea ice) (Durner et al. 2007) • Decline in ringed sea population and health (Harwood et al. 2000; Smith and Harwood 2001) • Continued decline in caribou populations (Gunn 1995; Post and Forschhammer 2008)	• Loss of income from sport hunting and the sale of furs and pelts • Less country foods

freeze-up and break-up) will have the most profound influences on ecosystems and wildlife, although predictions of precisely how these changing conditions will affect wildlife are difficult because little is known about the adaptability of particular species (Anisimov et al. 2007; Carmack and Macdonald 2002; Hinzman et al. 2005). Despite limitations in predictability, there are concerns that degradation of habitat or feeding conditions will cause dramatic declines in many wildlife populations that Inuit depend on for subsistence and livelihoods (Durner et al. 2007; Ono 1995; Solomon 2007). Furthermore, projected reductions in sea ice cover, more unstable sea ice conditions and trends towards later freeze-up and earlier break-up will likely continue to exacerbate risks associated with travel on the sea ice and compromise travel routes to hunting grounds.

3.5.2 Infrastructure: Future Exposure-Sensitivities

Future exposure-sensitivities for Tuktoyaktuk's infrastructure may arise due to instability of permafrost under buildings, flooding and coastal erosion (Table 3.7). Couture et al. (2002) estimated that more than 40% of

Table 3.7 Future climate change projections and possible future exposure-sensitivities related to infrastructure

Future climate change projection	Future exposure-sensitivities
Building foundations	
• Longer summer season and stronger storm events increase potential erosion (Johnson et al. 2003; Manson and Solomon 2007) • Permafrost thaw due to warming (Manson et al. 2005; Furgal and Prowse 2008)	• Damage to buildings and associated costs for repair • Cost to relocate buildings close to eroding shorelines
Municipal services	
• Strong storm events coupled with sea level rise cause flooding (Couture et al. 2002; Manson and Solomon 2007)	• Road closings inhibit movement of trucks that deliver propane and remove sewage
Roads and transportation	
• Warmer temperatures and increased fall precipitation cause shorter season for ice road	• Shorter time for access to Tuktoyaktuk via ice road and higher cost for goods

Tuktoyaktuk's buildings were constructed using 'shallow' foundation systems that are very susceptible to frost heaving and slippage. Projections of climate change indicate that warmer summer air temperatures and long summers may lead to permafrost melting and cause significant damage to buildings within the next 50 years (Furgal and Prowse 2008; Manson and Solomon 2007). These risks can be alleviated to a large extent by construction techniques that minimize disturbance to the upper layer of permafrost and do not transfer heat to the ground.

Shoreline protection has slowed the recent rates of erosion along Tuktoyaktuk's shoreline. Future rates of erosion are difficult to project since it is unknown how recent shoreline protection measures will respond to extreme storm events. Several climate projections are particularly relevant for coastal processes and rates of erosion, including warmer summer temperatures, longer open water seasons, increased frequency and intensity of storms in late summer and autumn, and sea level rise (Manson et al. 2005; Manson and Solomon 2007). Estimations of future erosion of Tuktoyaktuk's shoreline indicate that within 25 years, several buildings will be damaged or destroyed (if not relocated) and the community's inner harbor may be exposed to storms and rapid erosion due to deterioration of a spit at the north end of the community and a small island at the mouth of the harbour (Couture et al. 2002; Johnson et al. 2003). Given Tuktoyaktuk's location on low-lying land and potential increases in storm magnitude and frequency, the community also faces flood risks. Extreme storm events could flood most of Tuktoyaktuk, including houses and the sewage and garbage lagoons (Couture et al. 2002).

3.5.3 Future Adaptive Capacity

The future capacity of community members to deal with climate change will likely depend on factors already influencing adaptation. These include, but are not limited to, access to income, changing levels of environmental knowledge and land skills, and flexibility in harvesting practices and institutions (e.g. harvesting quotas).

In both communities, access to income is a key factor determining whether or not people are able to participate in subsistence. Mechanized transportation is expensive to purchase, operate, and maintain and fuel prices continue to rise. Together with the cost of ammunition, food, and other supplies, participating in harvesting activities can be an expensive undertaking. Climatic changes which require adaptations that necessitate economic responses (e.g. alternative travel routes requiring additional fuel, changing mode of transportation – snowmobile to boat) further exacerbate financial stresses affecting subsistence. Access to income sometimes limits participation in subsistence and adaptive capacity to deal with changing conditions but it also represents a strategic policy entry point to enhance adaptive capacity to deal with expected future climate change. For example, harvester assistance programs, job focused skills training, economic diversification, and greater educational opportunities are initiatives that could be commenced or, if already underway, could be further invested in. Providing harvesters with stable sources of income would enhance their involvement in subsistence and also strengthen their capacity to adapt to changing climate conditions.

An important component of Inuit adaptive capacity to deal with variable environmental conditions is the traditional environmental knowledge and land skills generated through hands-on experience and transmitted among generations. Hunters manage the risks associated with hunting by taking precautions, knowing what equipment to take and what routes to travel, and being aware of critical signs in the environment (Pearce et al. 2010). However, community members in both communities are concerned that the knowledge and skills necessary for safe and successful hunting are no longer being generated or transmitted effectively. Younger generation Inuit are spending considerably less time involved in subsistence activities outside of organized land camps and occasional hunting trips and there is a concern that youth are at greater risk of harm from changing environmental conditions because they are not well-equipped to deal with them. Possible initiatives to address this concern include integrating environmental knowledge and land skills into school curriculum, developing a harvester-mentorship program, and/or holding skill development workshops in the communities. Currently, research is underway in Ulukhaktok to document what knowledge and skills are (and are not) being successfully transmitted to younger generation community members. This will provide an indication of the knowledge and skills to target in skill development initiatives. Citing the growing population of Inuit youth and declining population of elders, initiatives to address the loss of environmental knowledge and land skills need to be addressed without delay.

In Tuktoyaktuk, the availability of funding is a central factor influencing adaptive capacity to deal with infrastructure risks and damage. The municipal government relies on transfer payments and approval from the territorial government for any undertakings related to shoreline protection. The federal government has also contributed funds in the past but does not have jurisdiction or responsibility for address community infrastructure damage. This situation creates a dilemma where the ability of local decision-makers to address these challenges is strongly determined by the political will and support from remote government bodies.

3.6 Conclusions

Exposure-sensitivities in Ulukhaktok and Tuktoyaktuk are associated with the reliance of community members on harvesting for livelihoods, subsistence and cultural fulfillment. In Ulukhaktok, current exposure-sensitivities include increased risks associated with travel on land and sea ice, compromised travel routes to hunting areas and changes in the health and availability of some wildlife important for subsistence. Current exposure-sensitivities in Tuktoyaktuk include compromised food security and health of wildlife as well as difficulties in preparing and storing traditional foods. While adaptive strategies are not the same in both communities, in both places they have been characterized by substitution of food sources (alternative wildlife or store-bought foods when preferred wildlife are not available), altering timing and modes for travel and harvesting, and taking extra precautions when traveling and harvesting. Tuktoyaktuk has also experienced risks to infrastructure due to shoreline erosion and degradation of permafrost that are exposure-sensitivities for buildings and other infrastructure. The community's primary means of adapting to these risks has been to install shoreline protection measures that are intended to slow rates of erosion.

Future exposure-sensitivities were estimated based on current conditions and projected changes due to climate change and other forces. Changes in the timing of seasonal events (break-up and freeze-up of sea ice), sea ice dynamics, wind patterns and precipitation will alter and degrade habitat for wildlife in the ISR. Declines in the health, breeding success and movement of wildlife in the future will generate further challenges for Inuit who depend on wildlife for livelihoods, food and culture.

Adaptive capacity for dealing with these exposure-sensitivities is variable within each community. In terms of harvesting exposure-sensitivities, flexibility in harvesting practices, access to income, the generation and transmission of traditional environmental knowledge and land skills, and wildlife management through quotas and other measures influence the capacity of community members to adapt. In relation to infrastructure exposure-sensitivities, limited financial resources constrain the community from taking proactive adaptive plans and actions, such as relocating the community to more stable land. These determinants of adaptation represent strategic policy entry points to help reduce vulnerabilities and enhance adaptive capacity to deal with expected future climate change.

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References

ACIA. 2005. In *Impacts of a Warming Arctic: Arctic climate impact assessment,* eds. C. Symon, L. Arris, and C. Grabhorn, 1042 pp. Cambridge, UK: Cambridge University Press.

Andrachuk, M. 2008. An assessment of the vulnerability of Tuktoyaktuk to environmental and socio-economic changes. Masters thesis, University of Guelph.

Anisimov, O.A., D.G. Vaughan, T.V. Callaghan, C. Furgal, H. Marchant, T.D. Prowse, H. Vilhjálmsson, and J.E. Walsh. 2007. Polar regions (Arctic and Antarctic). In *Climate change 2007. Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change,* eds. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, 653–685. Cambridge, UK: Cambridge University Press.

Atkinson, D.E. 2005. Observed storminess patterns and trends in the circum-Arctic coastal regime. *Geo-Marine Letters* 25: 98–109.

Barber, D.G., J.V. Lukovich, J. Keogak, S. Baryluk, L. Fortier, and G.H.R. Henry. 2008. The changing climate of the arctic. *Arctic* 61: 7–26.

Barry, R.G., R. Armstrong, T. Callaghan, J. Cherry, S. Gearheard, A. Nolin, D. Russell, and C. Zöckler. 2007. Snow. In *Global outlook for ice and snow,* ed. J. Eamer, p. 52. Birkeland, Norway: United Nations Environment Programme.

Carmack, E.C., and R.W. Macdonald. 2002. Oceanography of the Canadian Shelf of the Beaufort Sea: A setting for marine life. *Arctic* 55: 29–45.

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V.M. Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton. 2007. Regional climate projections. In *Climate change 2007. The physical science basis. Contribution of working group I to the fourth assessment report of the intergovern-mental panel on climate change,* eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K.B. Averyt, M.M.B. Tignor, H.L. Miller, Jr, and Z. Chen, 847–940. Cambridge, UK: Cambridge University Press.

Cohen, S.J. 1997. *Mackenzie basin impact study (MBIS): Final report,* 372 pp. Downsview, Ontario: Atmospheric Environment Services, Environment Canada.

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

Condon, R. 1987. *Inuit youth: Growth and change in the canadian arctic*. New Brunswick, NJ: Rutgers University Press.

Couture, R., S. Robinson, M. Burgess, and S. Solomon. 2002. Climate change, Perma-frost, and community infrastructure: A compilation of background material from a pilot study of Tuktoyaktuk, Northwest territories. *Geological Survey of Canada Open File* 3867: 83.

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

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

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

Durner, G.M., D.C. Douglas, R.M. Nielson, S.C. Amstrup, and T.L. McDonald. 2007. Predicting the future distribution of polar bear habitat in the polar basin from resource selection functions applied to 21st century General circulation model projections of sea ice. In, USGS Science Strategy to Support U.S. Fish and Wildlife Service Polar Bear Listing Decision. 55 pp.

Environment and Natural Resources. 2006a. Press release: Barren-ground Caribou survey results released. Available from http://www.exec.gov.nt.ca/currentnews/prDetails.asp?varPR_ID=914 [last updated 8 September 2006]

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

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

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

Ford, J., T. Pearce, F. Duerden, C. Furgal, and B. Smit. 2010. Climate change policy responses for Canada's Inuit population: the importance of and opportunities for adaptation. *Global Environmental Change* 20(1): 177–191.

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

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

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

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

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

GNWT 2008. NWT Climate change impacts and adaptation report. 31.

Gunn, A. 1995. Responses of arctic ungulates to climate change. In *Human ecology and climate change: People and resources in the far north,* eds. D.L. Peterson, and D.R. Johnson, 89–104. Washington, DC: Taylor & Francis.

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

Hamlet of Tuktoyaktuk. 1984. Community plan for the hamlet of Tuktoyaktuk, N.W.T.

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

Hinzman, L.D., N.D. Bettez, W.R. Bolton, F.S. Chapin, M.B. Dyurgerov, C.L. Fastie, B. Griffith, R.D. Hollister, A. Hope, H.P. Huntington, A.M. Jensen, G.J. Jia, T. Jorgenson, D.L. Kane, D.R. Klein, G. Kofinas, A.H. Lynch, A.H. Lloyd, A.D. McGuire, F.E. Nelson, M. Nolan, W.C. Oechel, T.E. Osterkamp, C.H. Racine, V.E. Romanovsky, R.S. Stone, D.A. Stow, M. Sturm, C.E. Tweedie, G.L. Vourlitis, M.D. Walker, D.A. Walker, P.J. Webber, J. Welker, K.S. Winker, K. Yoshikawa. 2005. Evidence and implications of recent climate change in northern Alaska and other Arctic regions. *Climatic Change* 72: 251–298.

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

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

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

Johnson, K., S. Solomon, D. Berry, and P. Graham. 2003. Erosion progression and adaptation strategy in a northern coastal community. 8th International Conference on Permafrost. Zurich, Switzerland: AA Balkema.

Kattsov, V., and E. Kallen. 2005. Future climate change: Modelling and scenarios for the Arctic. In *Arctic climate impact assessment (ACIA)sScientific report,* eds. C. Symon, L. Arris, and C. Grabhorn, 99–150. Cambridge, UK: Cambridge University Press.

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

Lemke, P., J. Ren, R.B. Alley, I. Allison, J. Carrasco, G. Flato, Y. Fuji, G. Kaser, P. Mote, R.H. Thomas, and T. Zhang. 2007. Observations: Changes in snow, ice and frozen ground. In *Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the intergovern-mental panel on climate change,* eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K.B. Averyt, M.M.B. Tignor, H.L. Miller, Jr, and Z. Chen, 337–383. Cambridge, UK: Cambridge University Press.

Manson, G.K., S.M. Solomon, D.L. Forbes, D.E. Atkinson, and M. Craymer. 2005. Spatial variability of factors influencing coastal change in the western Canadian Arc-tic. *Geo-Marine Letters* 25: 138–145.

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

Nagy, J.A., and D. Johnson. 2006. Estimates of the number of barren-ground Caribou in the cape Bathurst and bluenose-West herds and Reindeer/Caribou on the Upper Tuktoyaktuk Peninsula Derived Using Post-Calving Photography. 66.

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

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

Nuttall, M., F. Berkes, B. Forbes, G. Kofinas, T. Vlassova, and G. Wenzel. 2005. Hunting, herding, fishing, and gathering: Indigenous peoples and renewable resource use in the Arctic. In *Arctic climate impact assessment (ACIA) scientific report*, eds. C. Symon, L. Arris, and C. Grabhorn, 649–690. Cambridge, UK: Cambridge University Press.

Ono, K.A. 1995. Effects of climate change on marine mammals in the far north. In *Human ecology and climate change: People and resources in the far north,* eds. D.L. Peterson, and D.R. Johnson, 105–121. Washington, DC: Taylor & Francis.

Pearce, T. 2006. Vulnerability and adaptation to environmental change in Ulukhaktok. Masters thesis, University of Guelph.

Pearce, T., J. Ford, G. Laidler, B. Smit, F. Duerden, M. Allarut, M. Andrachuk, S. Baryluk, A. Dialla, P. Elee, A. Goose, T. Ikummaq, E. Joamie, F. Kataoyak, E. Loring, S. Meakin, S. Nickels, K. Shappa, J. Shirley, and J. Wandel. 2009. Community collaboration and climate change research in the Canadian Arctic. *Polar Research* 28(1): 10–27.

Post, E., and M.C. Forschhammer. 2008. Climate change reduces reproductive success of an Arctic herbivore through trophic mismatch. *Philosophical Transactions of the Royal Society* B 363: 2369–2375.

Pearce, T.D., B. Smit, F. Duerden, J. Ford, A. Goose, and F. Kataoyak. 2010. Inuit vulnerability and adaptive capacity to climate change in Ulukhaktok, Northwest Territories, Canada. *Polar Record* 46(237):157–177. doi:10.1017/S0032247409008602.

Rachold, V., and G. Cherkashov. 2003. Arctic coastal dynamics: Report of the 4th international workshop. St. Petersburg, Russia, international arctic sciences committee (IASC), the international permafrost association (IPA) and a regional project of IGBP-LOICZ (International Geosphere-Biosphere Programme – Land- Ocean Inter-actions in the Coastal Zone), 229 pp.

Reimnitz, E., and D.K. Maurer. 1979. Effects of storm surges on the Beaufort Sea coast, northern Alaska. *Arctic* 32: 329–344.

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

Serreze, M., M.M. Holland, and J. Stroeve. 2007. Perspectives on the arctic's shrinking sea ice cover. *Science* 316: 1533–1536.

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

Smit, B., G. Hovelsrud, and J. Wandel. 2008. CAVIAR: Community adaptation and vulnerability in arctic regions. University of Guelph, Department of Geography, Occasional Paper No. 28.

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

Solomon, S. 2007. Geophysical changes in the arctic region – Defrosting in the arctic: Climate change and the coast. Coastal Zones at Risk Scientific Workshop, Tromsø, Norway, 1–3 October 2007.

Solomon, S., and E. Hart. 2000. Storminess in the Western arctic: Extending the Histori-cal record using Hudson's Bay Company Archives. http://www.eman-rese.ca/eman/reports/publications/99_national/hudsonbay.html. [last updated 7 September 2000].

Solomon, S., D.L. Forbes, and B. Kierstead. 1993. Coastal impacts of climate change: Beaufort Sea erosion study. *Geological Survey of Canada Open File* 2890: 35.

Solomon, S.M. 2005. Spatial and temporal variability of shoreline change in the Beau-fort-Mackenzie region, Northwest Territories, Canada. *Geo-Marine Letters* 25: 127–137.

Sou, T., and G. Flato. 2009. Sea ice in the Canadian Arctic Archipelago: Modeling the past (1950–2004) and the future (2041–60). *Journal of Climate* 22: 2181–2198.

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

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

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

Walsh, J., O. Anisimov, J. Hagen, T. Jakobsson, J. Oerlemans, T.D. Prowse, V. Romanovsky, N. Savelieva, M. Serreze, A. Shiklomanov, I. Shiklomanov, and S. Solomon. 2005. Cryosphere and hydrology. In *Arctic Climate Impact Assessment (ACIA) Scientific Report*, eds. C. Symon, L. Arris, and C. Grabhorn, 183–242. Cambridge, UK: Cambridge University Press.

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