Chapter 7

Health Impacts of Climate Change in Canada's North

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7.1 INTRODUCTION

There is strong evidence that the Canadian Arctic, like other circumpolar regions, is already experiencing changes in its climate (Huntington et al., 2005; McBean et al., 2005; Ouranos, 2005; Bonsal and Prowse, 2006). According to the *Arctic Climate Impact Assessment,* over the past 30 to 50 years the western and central Canadian Arctic have experienced a general warming, most dramatically during winter months, of approximately 2–3°C (Weller et al., 2005). Although significant cooling (-1.0 to -1.5°C) was reported for the period of 1950–1998 for the extreme northeast regions, warming is now reported for recent years (Zhang et al., 2000). As well, community residents, Aboriginal[1] hunters and Elders have reported significant warming throughout the North in recent decades, corroborating these scientific observations and describing the impacts these changes have already had (Huntington et al., 2005; Nickels et al., 2006). According to both scientific measurements and local knowledge, these climatic changes have led to significant decreases in the extent and thickness of winter sea ice throughout Canadian Arctic waters, melting and destabilization of permafrost, increased coastal erosion of low-lying areas, and shifts in the distribution and migratory behaviour of some Arctic wildlife species. The current and future implications of these changes for human communities in the North are far-reaching. The complex changes in northern climate and environmental systems observed to date require greater understanding and involvement by individuals and institutions to accurately assess the impacts of these changes on the health of some of Canada's most vulnerable populations and to aid in the development of effective adaptation strategies to minimize risks to health in this region (Ford et al., 2006; Furgal and Séguin, 2006).

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The Canadian North warrants particular attention in this Assessment for a number of reasons. Despite a small and dispersed population, the circumpolar Arctic is recognized as being an increasingly significant region in global environmental, political and economic systems. Contaminant production and use, predominantly in more industrialized regions of the world, their transport to and within the North, and recognition of their negative impacts on the health of Arctic residents have led to finalizing global environmental health agreements such as the Stockholm Convention (Downey and Fenge, 2003). Polar regions are important for the rest of the country and world for climate regulation and because they provide extensive areas that remain wild and relatively unaffected by human activities; these regions serve as critical areas for many culturally and otherwise important migratory species that are important components of global biodiversity (Chapin et al., 2005). The increasing level of mineral exploration and extraction activities, the significant but as yet unharnessed oil and gas reserves, and the rising importance of northern development sites to global markets has increased the importance of this region in the global economy. With warming and projected decreases in sea ice cover and extent, and the potential increased

1 In this chapter, "Aboriginal" refers collectively to those individuals recognized as "First Nations," "Inuit" or "Métis" in Canada. Where research results are specific to any one group, they are identified accordingly in the text.

access and travel through the Northwest Passage in the future, the Canadian North is projected to garner significant attention, and to undergo potentially significant further and irreversible change.

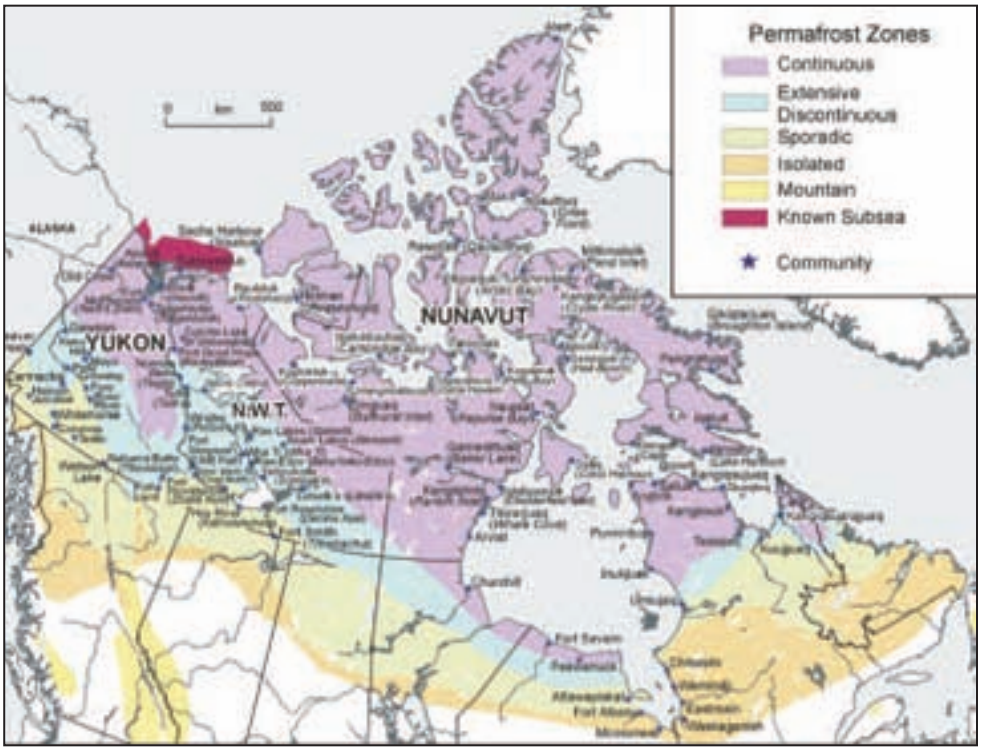
The increased pressures that polar regions are experiencing imply that they are approaching critical thresholds (such as thawing of permafrost and vegetation change), yet the exact timing and nature of these thresholds are not well known. Crossing these thresholds will likely trigger a cascade of effects, with significant impacts (some positive and some negative) on human health and well-being (Chapin et al., 2005). In fact, some regions are already reporting changes and associated impacts, many of which are presented in sections of this chapter and elsewhere (Furgal and Séguin, 2006). These northern communities and the northern public health system may very well be a bellwether for some of the more vulnerable populations in other parts of the country. What is already taking place and how communities are adapting may provide valuable knowledge to support proactive adaptation in other regions. Finally, there is a sense of environmental injustice in relation to the issue of climate change and northern health. The Arctic regions are reported to be the first to experience climate change and its related impacts, and these regions are where change may be the greatest (Intergovernmental Panel on Climate Change (IPCC), 2001). These regions are also where large groups of Aboriginal people reside; they are still inextricably tied to their local environments through culture and tradition, and a reliance upon the natural environment for many aspects of livelihoods, health and well-being. These regions are also undergoing rapid social, cultural, political and economic change, which place stresses on communities and populations both from the inside and externally. Northern residents (and the regions in which they live) are in general among the lowest proportional contributors to greenhouse gas (GHG) emissions in the country. However, it is these populations, and particularly Aboriginal residents, who are the most exposed and potentially most vulnerable to climate change health impacts in Canada.

Research on climate change and health impacts in northern Canada, as in other circumpolar regions, is in its infancy (Berner, 2005; Hassi et al., 2005; Furgal and Séguin, 2006). Recently, particular attention has been given to impacts on northern Aboriginal populations. Some limited work, incorporating Aboriginal knowledge and local observations of environmental change along with scientific assessments of the impacts associated with these and other kinds of change in remote and rapidly changing communities, has been completed (Berner et al., 2005; Huntington et al., 2005; Furgal and Séguin, 2006). This chapter assesses the current level of exposure to climate-related hazards, health impacts and vulnerabilities, as well as the capacity of northern communities to adapt to the risks that climate change is posing for Canada's northern populations.

7.1.1 Climate Change and the Canadian North

In the context of this Assessment, the "North" is referred to here as the three territorial administrative regions (the Yukon, Northwest Territories (NWT) and Nunavut) north of 60°, Nunavik (Arctic Quebec north of 55° N) and the north coast of Labrador within the Nunatsiavut land claim settlement. The latter two comprise communities with proportionately large Aboriginal populations and share many biogeographical characteristics with the other Arctic regions of Canada. It is a vast area encompassing 112 communities of varying languages and cultures, including many different ecological zones, and makes up approximately 60% of the Canadian land mass (Figure 7.1).

Figure 7.1 Communities, political boundaries and permafrost zones of the Canadian North



Note: Includes 112 communities spread across three territories and the northern regions of two provinces.

Source: Furgal and Prowse, 2008.

There are five major distinct physical geographic regions across the North: the Canadian Shield, Interior Plains, Arctic Lowlands, Cordillera and Innuitian Region (Fulton, 1989) (Figure 7.2). The Canadian Shield of the central and eastern Arctic is characterized by rolling terrain and exposed rock, lakes and rivers, and it extends to the mountainous regions of the eastern islands (e.g. Baffin Island, Arctic Cordillera). The low-lying Interior Plains of the central Arctic stretch west to the complex Cordillera regions (Boreal and Taiga Cordillera). Steep mountainous landscapes and some of the highest peaks in North America are characteristic of this area (Prowse, 1990; French and Slaymaker, 1993). The Cordillera separates the interior of the continent from the Pacific Ocean, and affects the movement of air masses and thus climate. Permafrost underlies significant portions of many of these regions and influences the development of infrastructure in the North. Along with the presence of permafrost, the underlying geography and geology have always influenced (and continue to influence) the climate, and the distribution of wildlife and other natural resources (e.g. minerals) and human settlement, activities and development today.

Figure 7.2 Physiographic and eco-regions of the Canadian North and their geographic and biological characteristics

Ecozone	Landforms	Climate	Vegetation	Wildlife
Arctic Cordillera	Massive icefields and glaciers cap the rugged mountains	Very cold and arid	Largely absent due to permanent ice and snow	Polar bear, walrus, seals, narwhal, whale
Northern Arctic	Lowland plains with glacial moraines in the West, and uplands with plateaux and rock hills in the East	Very dry and cold	Dominated by herbs and lichen	Caribou, muskox, wolf, arctic hare, lemming
Southern Arctic	Broadly rolling upland and lowland plains	Long, cold winters and short, cool summers	Dwarf shrubs that decrease in size to the north	Moose, muskox, wolf, arctic fox, grizzly and polar bear, caribou
Taiga Plains	Broad lowlands and plateaux, incised by major rivers	Semi-arid and cold	Dwarf birch, Labrador tea, willows and mosses	Moose, woodland caribou, wolf, black bear, marten
Taiga Shield	Rolling terrain with uplands, wetlands and innumerable lakes	Subarctic continental climate, with low precipitation	Open forests and arctic tundra	Caribou, moose, wolf, snowshoe hare, black and grizzly bears
Taiga Cordillera	Steep, mountainous topography with sharp ridges and narrow valleys	Dry, cold winters and short, cool summers	Shrubs, mosses, lichens, dwarf birches, willows	Dall's sheep, caribou, lynx, wolverine
Boreal Plains	Level to gently rolling plains	Moist climate with cold winters and moderately warm summers	Spruce, tamarack, jack pine, white birch, balsam, poplar	Woodland caribou, mule deer, coyote, boreal owl
Boreal Cordillera	Mountain ranges with high peaks and extensive plateaux	Long, cold, dry winters and short, warm summers	Spruce, alpine fir, trembling aspen, white birch	Woodland caribou, Dall's sheep, mountain goat, marten, ptarmigan

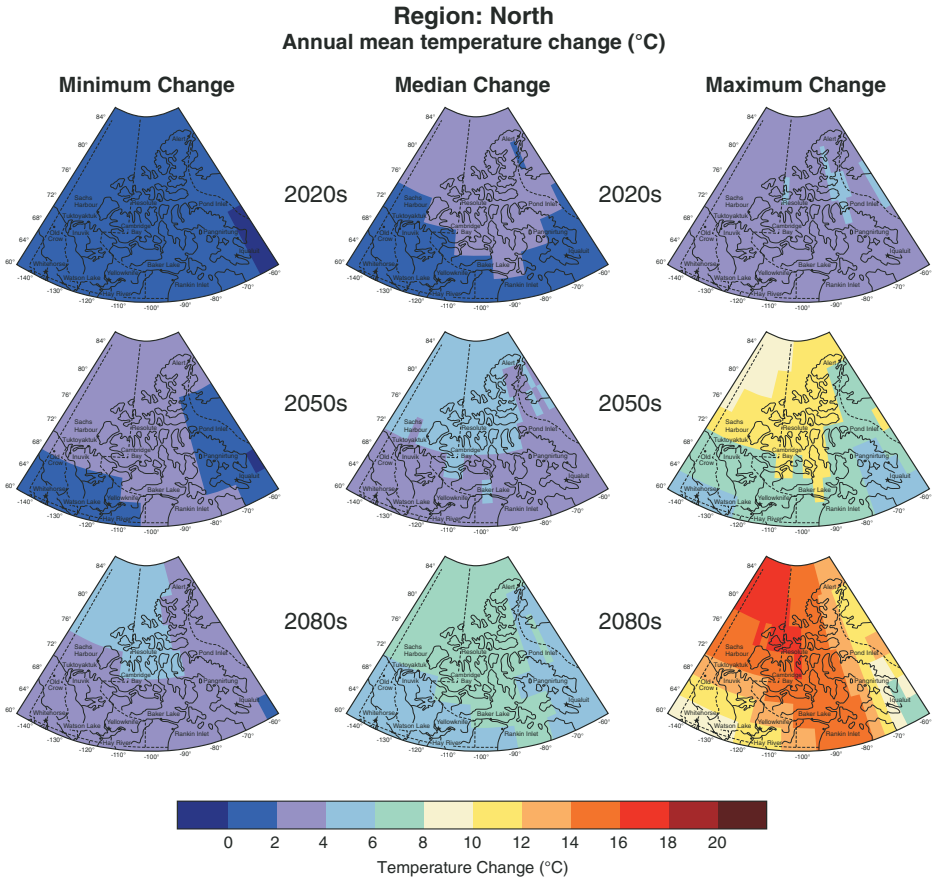
Source: Adapted from Fulton, 1989; Furgal et al., 2003.

Climate model projections for the Canadian North appear to indicate that the recently observed rates of change across the North will continue (McBean et al., 2005). Coupled with a unique degree of sensitivity of northern ecosystems, the impacts of climate change in the Arctic over the next hundred years are expected to surpass that in many other regions of the country and the world. However, the complexity of responses in biological and human systems, and the fact that northern populations are also experiencing stress from many other sources, must also be considered. The projections of impacts resulting from changes in the climate system, which are often examined in isolation, must be considered in the context of other driving forces of change—potentially increasingly important ones in relation to northern health and well-being.

Climate simulations consistently indicate a "polar amplification" phenomenon, which is greater warming in the northern high latitudes compared with warming over the entire globe (Christensen et al., 2007). For the Arctic regions, climate models predict an increase in temperature of 2–4°C by the middle of the 21st century, and an increase of 4–7°C by the end of the century, depending on the GHG emission scenario used (Kattsov et al., 2005; Weller et al., 2005) (Figure 7.3). In the Canadian Arctic the largest seasonal warming is projected to occur in the autumn and winter over the Arctic Ocean, with decreased seasonal warming in the summer (Furgal and Prowse, 2008). This trend extends onto land, though it is much less pronounced (Kattsov et al., 2005; Christensen et al., 2007). Despite the general warming trend, there is considerable spatial variability in expected temperature change in the Arctic.

Simulations also show a general increase in precipitation (10–28%) over the Arctic by the end of the 21st century, which is robust among models and can be attributed to the projected warming and related changes in atmospheric moisture content (Christensen et al., 2007). This increase in precipitation also exhibits spatial variability in the Canadian Arctic, with the greatest projected increase to occur over regions in the high Arctic and Arctic Ocean (30–40%), and the smallest to occur in the Atlantic sector (<5–10%) (Kattsov et al., 2005; Christensen et al., 2007; Furgal and Prowse, 2008). The percentage increase in precipitation is projected to be largest in the winter season and smallest in the summer, which is consistent with the warming projections (Christensen et al., 2007; Kattsov et al., 2005).

Figure 7.3 Atmosphere-Ocean General Circulation Model projected annual temperature changes over the Canadian North for three 30-year periods: 2020s, 2050s and 2080s



Source: Furgal and Prowse, 2008.

These projected trends in temperature and precipitation regimes throughout the Canadian Arctic highlight the need to better understand the current status of and changes in relationships between northern residents and their environment (e.g. cold and heat exposure, use and contact with snow, ice, wildlife and other environmental resources). This understanding must consider seasonality and regional specificity because a variety of physical processes, feedback systems, and natural variations will cause uneven climate impacts across the North. These regional and seasonal specificities imply differential environmental health risks in these regions.

7.1.2 Focus of the Chapter

Recent scientific assessments have been conducted in the Arctic that incorporate evaluations of various aspects of change (social, environmental, political) and their impacts on human populations. These include the work performed by the *Third Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC, 2001), the Arctic Monitoring and Assessment Program (AMAP) (AMAP, 2002), the *Arctic Climate Impact Assessment* (ACIA) (ACIA, 2005), the *Arctic Human Development Report* (AHDR) (AHDR, 2004) and the *Millennium Ecosystem Assessment* (Chapin et al., 2005). Much of this work has focussed on describing impacts of change. In regard to their treatment of human impacts, the conclusions of previous assessments have tended to be speculative in nature due to a lack of locally specific data, and sparse impact and adaptation research at the local scale. However, they are extremely valuable because they summarize the state of knowledge and identify knowledge gaps regarding climate change impacts in circumpolar regions, and thus can guide current and future research activities.

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The current chapter adds to the existing body of knowledge by taking a vulnerability approach in the assessment of climate change impacts on health in the Canadian North. The limitations imposed by the lack of local-scale qualitative and quantitative data on the subject remain. However, this chapter attempts to provide a synthesis of key existing and future health vulnerabilities by also considering current and future factors that influence the exposure of local populations and their ability to respond (adaptive capacity) to changes in local climatic conditions. The term "vulnerability" means "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC, 2007, p. 21).

7.1.3 Methods

Climate change takes place amid a number of interacting social, economic and environmental variables across local, regional, national and international scales. It is therefore important to consider the vulnerability of "systems" which connect humans to their environment, and support ways of life, livelihoods and health. To assist communities and individuals in developing strategies to enhance their adaptive capacity and ultimately reduce vulnerability, it is imperative to understand the current status of factors that affect this vulnerability. To achieve this, an approach similar to that used by others (World Health Organization (WHO),

2003; Ebi et al., 2006) has been taken. A step-wise process describes the current distribution and burden of climate-sensitive diseases; identifies and describes current capacities to reduce the impacts of these diseases; reviews the health implications of the potential impact of climate variability and change on various sectors, estimating future potential impacts; and finally synthesizes the results of the assessment and identifies potential adaptation measures to reduce the negative health effects. Despite the lack of local-scale data from climate and health-related work in the Canadian North, information does exist on the status and trends in various northern sectors about the current exposure to environmental hazards and the adaptive capacity to respond to change; this information aids in an assessment of this type.

This chapter first describes the current distribution and burden of climate-influenced health outcomes, as well as the status of selected variables reported to influence vulnerability and adaptive capacity (see Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada). A discussion of the state of knowledge about the relationships between climate-related variables and health impacts in northern regions is then provided. Via a predominantly qualitative analysis, employing a process of data triangulation (Farmer et al., 2006) or weight-of-evidence approach, the chapter draws upon various qualitative and quantitative sources of data to review key vulnerabilities and provide an initial assessment of the factors that influence adaptive capacity. The chapter then presents a review of current health adaptations in reaction to climate and environmental change in the Canadian North. It concludes with a summary of key knowledge gaps and recommendations for research and action on these issues.

The chapter draws on information from the Arctic Monitoring and Assessment Program, *Arctic Human Development Report, Arctic Climate Impact Assessment* and the *Millenium Ecosystem Assessment* as they pertain to the Canadian Arctic. These assessments are an assemblage of scientific review and expert opinion. This chapter uses, where available, peer-reviewed studies on this topic in the Canadian North as well as grey literature, and research and policy reports. Some of this work is specific to climate and health; much is more generally oriented toward environmental change and human impacts. This work comes from the fields of health and medical sciences, as well as anthropology, sociology, human ecology and human geography. Local reports of observations of change and perspectives on impacts presented in workshop reports and community-based projects are also used, reflecting much of the recent work done in the Canadian Arctic. Where possible, the methods used to collect these various sources of data are discussed in order to assess the confidence and utility of the information for the assessment of current and future vulnerability.

The data used in the assessment include both quantitative and qualitative survey information (e.g. Regional Health Survey, Aboriginal Peoples Survey, census statistics), Aboriginal knowledge and observations on changes and impacts, and indicators of organization and community adaptive capacity. In some cases, Aboriginal knowledge and local reports are the best and only local-scale data regarding individual exposure and health vulnerabilities to climate change in northern communities (Furgal and Séguin, 2006). Much of this information has been gathered either from projects using semi-directed interview methods (Huntington et al., 2000; Furgal et al., 2002) or a small workshop format (Nickels et al., 2002). Qualitative analysis of these various sources (e.g. more than 20 community workshops and Aboriginal organizational reports focussed on the topic of environmental change and community impacts) was conducted to identify indications of locally observed climate changes and health impacts, which were organized by health determinants in support of this assessment chapter (Barron, 2006).

7.2 NORTHERN DEMOGRAPHICS, HEALTH AND WELL-BEING, AND SOCIO-ECONOMIC STATUS

Health vulnerabilities to climate change are related to current and future levels of exposure and the ability to respond. This adaptive capacity—the ability to respond—can be influenced by a number of factors including existing health and socio-economic status (see section 7.5). A short review of pertinent demographic and health statistics potentially influencing Northerners' vulnerability to the health impacts of climate change is presented here. Because the statistics are influenced by demographic structure and population size, the crude rates shown for some indicators are to be interpreted with caution.

7.2.1 Demographics

While most of Canada's population lives in cities south of the 60° N parallel, approximately 150,000 live in Canada's North. Most of the northern population lives in three territories, with comparatively smaller but significant populations living in the northern regions of Quebec (Nunavik) and Labrador (in the Inuit Settlement Area of Nunatsiavut) (Table 7.1). Still a relatively sparsely inhabited region of the country, the North has experienced significant demographic, social, economic and political change in recent decades. In the late 1950s and 1960s, significant population and economic growth, associated with resource development and the establishment of public administration, took place; however, this trend has since slowed (Chapin et al., 2005). During that time, many Aboriginal people who were living a traditional lifestyle on the land were settled permanently in communities. Most population growth since the establishment of communities has occurred primarily in the three main urban centres (Whitehorse, Yellowknife and Iqaluit), and population density remains low outside of these locations (Bogoyavlenskiy and Siggner, 2004). Since the 1980s, much of the population growth has been attributed to an increase in the non-Aboriginal population; this is associated with resource development and public administration (Bogoyavlenskiy and Siggner, 2004; Chapin et al., 2005). The northern population is projected to continue to grow in the coming years, most significantly in the NWT where the population is expected to surpass 50,000 residents within the next 25 years (Table 7.1). This is likely attributed, at least in part, to industrial development associated with the Mackenzie Valley pipeline project and other mineral extraction activities in that region, and increases in employment opportunities.

Table 7.1 Current (2005) and projected (2031) populations (thousands) for Canadian northern regions

	2005 Population	Mean Annual Growth Rate for Scenario 3 (range of scenarios 1–6)	Projected Population in 2031 for Scenario 3 (range of scenarios 1–6)
Canada	32,270.5	7.3 (4.5–10.0)	39,024.4 (36,261.2–41,810.0)
Labrador	23.9	*	*
Nunavik	9.6	*	*
Nunavut	30.0	4.0 (1.2–6.6)	33.3 (30.0–35.6)
Northwest Territories	43.0	9.1 (5.8–11.4)	54.4 (49.9–57.7)
Yukon	31.0	3.6 (0.7–5.5)	34.0 (31.5–35.7)

Note: Scenario 3 assumes medium growth and medium migration rates with medium fertility, life expectancy, immigration and interprovincial migration (as outlined in Statistics Canada, 2006b).

* Data not available at the regional level included in this chapter.

Source: Statistics Canada, 2006b.

Today, the northern population is, on average, rapidly growing compared with the rest of Canada. Crude rates of births and mortality vary among regions. However, in general they are much higher in the North than the Canadian average (Tables 7.2, 7.3). Growth in northern populations, and among Aboriginal groups in particular, has been largely due to an increase in medical services and a reduction in infant mortality and mortality caused by infectious diseases, such as tuberculosis and vaccine preventable diseases of childhood, since the mid-part of the last century.

Table 7.2 Selected health indicators for Canadian northern regions

Indicator	Canada	Yukon	NWT	Nunavut	Nunavik	Labrador*
Public health spending per capita ($)	2,535	4,063	5,862	7,049	†	†
Crude birth rates (live births per 1,000 residents) (2003)‡	10.6	11.0	16.6	26.0	†	8.9
Life expectancy at birth (males, 2002)	75.4	73.9	73.2	67.2	63.3	73.6
Life expectancy at birth (females, 2002)	81.2	80.3	79.6	69.6	70.2	78.7
Infant mortality rate (per 1,000 live births, 500 grams or more, 2001)	4.4	8.7	4.9	15.6	17.8	†
Low birth weight rate (% of births less than 2,500 grams)§	5.5	4.7	4.7	7.6	6.7§	†
Potential years of life lost due to unintentional injury (deaths per 100,000 residents)	628	1,066	1,878	2,128	3,853§	†
Self-reported health (% aged 12 and over reporting very good or excellent health)	59.6	54	54	51	51	64
Physical activity (% aged 12 and over reporting physically active or moderately active)#	42.6	57.9	38.4	42.9	†	48.7

* Data from the former Health Labrador Corporation, which provided services to all of Central, Western and Coastal Labrador, including Black Tickle and points north (this organization merged with Grenfell Regional Health Services in 2005 to form Labrador-Grenfell Health).

† Data not available at the regional level included in this chapter.

‡ The population estimates used for the 2003 birth and fertility rate calculations are July 1, 2003 updated postcensal estimates, adjusted for net census undercoverage and include non-permanent residents. Source: Statistics Canada, 2004a.

§ Low birth weight is average from 1999–2003. Source: INSPQ, 2006.

Population aged 12 and over reporting level of physical activity, based on their responses to questions about the frequency, duration and intensity of their participation in leisure-time physical activity.

Source unless otherwise indicated: Statistics Canada, 2003.

Table 7.3 Selected crude mortality rates by cause (per 100,000 deaths) for Canadian northern regions

Indicator	Canada	Yukon	NWT	Nunavut	Nunavik*	Labrador
Total mortality rate (per 1,000) (2004)‡	7.1	5.4	3.6	4.1	7.1	8.3†
Major cardiovascular diseases	233.2	111.3	118.5	78.9	†	†
Acute myocardial infarction	58.9	6.5	35.5	10.3	†	†
Deaths due to heart attacks	52.1	37.1	28	3.7	†	†
Lung cancer	48.2	73.2	61	209.5	†	†
Accidents, unintentional injuries	28.6	65.5	59.2	30.9	†	†
Transport accidents (motor vehicle, other land transport, water, air and unspecified)	9.9	19.6	16.6	27.5	†	†
Accidental drowning	0.8	9.8	7.1	<0.5	†	†
Intentional self-harm (suicide)	11.9	19.6	23.7	106.4	131.2	†

Note: Crude mortality rates per 100,000 deaths in 2003 unless otherwise noted.

* Source: INSPQ, 2006.

† Not available at the regional level included in this chapter.

‡ Population estimates used for the 2003 mortality rate calculations are July 1, 2003 updated postcensal estimates, adjusted for net census undercoverage and included non-permanent residents (Statistics Canada, 2004a).

Source unless otherwise indicated: Statistics Canada, 2006a.

The northern population is considerably younger than the national average, with Nunavut and Nunavik having significant segments of their population under the age of 15 years. As well, a significantly smaller percentage of residents are over the age of 65 in the North compared with the rest of the country (Table 7.4). This combination makes for dependency ratios slightly lower than the national average in the Yukon and the NWT, yet higher in Nunavut. Based on Statistics Canada projections for the next 25 years, the North will continue to be a predominantly young population compared with the rest of Canada. However, with a growing percentage of people over the age of 65, the dependency ratios will increase across the territories as well. This is most significant in the Yukon where the dependency ratio is projected to increase from 33.6 to 55.8 over the next quarter century, predominantly associated with an aging population (Table 7.4). Comparable statistics are not available at the regional level for Nunavik and Labrador (north coast or Nunatsiavut Settlement area).

Table 7.4 Comparison of current (2006) and projected (2031) median age and population dependency ratios for Canada and northern regions under moderate population projection Scenario 3

Indicator	Canada current (projected)	Yukon current (projected)	NWT current (projected)	Nunavut current (projected)	Nunavik current (projected)	Labrador current (projected)
Median Age	38.8 (44.3)	37.6 (40.7)	30.8 (35.7)	23.0 (24.5)	22.2 (*)	*
% Aged 0-14	24.9 (23.5)	23.9 (25.0)	33.7 (31.3)	54.3 (50.9)	35.1(*)	*
% Aged 65 and over	19.0 (37.7)	9.8 (30.8)	6.9 (23.5)	4.4 (9.1)	3.0 (*)	*
Total dependency ratio	43.9 (61.3)	33.6 (55.8)	40.6 (54.8)	58.7 (60.0)	56.6 (*)	*

Note: Scenario 3 assumes medium growth and medium migration rates with medium fertility, life expectancy, immigration and inter-provincial migration (as outlined in Statistics Canada, 2006b).

* Data not available at the regional levels included in this chapter.

Source: Statistics Canada, 2006b; INSPQ, 2006 (Nunavik data).

7.2.2 Population Density

Nearly two thirds of Canadian northern communities are coastal, and the large majority are small and isolated; only three centres of more than 5,000 people exist. In some regions, the majority (67% in Nunavut) of the population live in communities of less than 1,000 people. However, these small communities (100–499 residents) represent only 11% of all northern residents (Bogoyavlenskiy and Siggner, 2004). Large centres account for significant proportions of some regional populations (e.g. the Yukon 58.7%, Table 7.5). As well, approximately 60% of northern communities are situated along coastlines, with this distribution reaching as high as 100% of communities in some regions (e.g. Nunavik, some regions of Nunavut and the NWT, Nunatsiavut). A smaller yet significant number are located in very mountainous areas.

Table 7.5 Population characteristics of Canadian northern regions

Indicator	Canada	Yukon	NWT	Nunavut	Nunavik	Labrador*
Population density (per km^2)	3.33	0.06	0.03	0.01	0.02	0.11
Urban population (% of total population)†	79.6	58.7	58.3	32.4	0.0	68.3
Aboriginal population (% of total population)‡	3.4	22.9	50.5	85.2	91.3	34.1

* Data from the former Health Labrador Corporation, which provided services to all of Central, Western and Coastal Labrador, including Black Tickle and points north (this organization merged with Grenfell Regional Health Services in 2005 to form Labrador-Grenfell Health).

† The official Statistics Canada definition of "urban" is used where "urban areas" are those continuously built-up areas having a population concentration of 1,000 or more and a population density of 400 or more per km^2 based on the previous census; rural areas have concentrations or densities below these thresholds.

‡ Aboriginal people are those who reported identifying with at least one Aboriginal group (e.g. North American First Nations, Métis or Inuit) and/or those who reported being of Treaty Indian status or of Registered Indian status as defined by the *Indian Act* and/or those who were members of an Indian Band or First Nation.

Source: Statistics Canada, 2001a (20% sample).

7.2.3 Aboriginal Populations

Just over half of northern residents are Aboriginal, and they represent diverse cultural and linguistic groups—from the 14 Yukon First Nations in the west to the Inuit of Nunatsiavut in the east, some of which have been in these regions for thousands of years. Nearly half of the residents in the North are non-Aboriginal and comprise a range of regional populations (from 8.1% in Nunavik to 77.1% in the Yukon, Table 7.5) (Statistics Canada, 2001a). Inversely, the number of Aboriginal residents as a proportion of regional or territorial populations is highest in Nunavik and then decreases as one moves toward Nunavut, the NWT and then to the Yukon. The majority of small communities are predominantly Aboriginal in composition and are places where various aspects of traditional lifestyles are still strong components of day-to-day life. When interpreting northern health statistics, which are often not available according to Aboriginal status, these ratios and their geographic distribution are important to note.

7.2.4 Health Status

In this chapter, health is regarded as a "state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 2006). This definition supports a multidimensional view of the concept of health and embraces the more traditional and holistic concepts of health held by many Aboriginal groups in the Canadian North and elsewhere. In general, the health status of the Canadian Northern population is lower than the national average (Tables 7.2, 7.3), and Northerners are more highly exposed to a variety of environmental hazards that account for significant proportions of common causes of mortality and hospitalization. The exposure and negative outcomes are even greater among northern Aboriginal residents (Institut national de santé publique du Québec (INSPQ), 2006). A variety of health status indicators are summarized in the text that follows; these help describe current health sensitivities and factors that may influence adaptive capacity in the context of climate change.

Life expectancy for both males and females living in the North is as much as 10 years less than the national average, and even lower among Aboriginal Northerners, likely due in part to factors such as higher rates of infant mortality (Table 7.2). The average life expectancy for all residents in regions in which Inuit comprise the majority of the population (Nunatsiavut, Nunavik, Nunavut and the Inuvialuit Settlement Region (ISR) of the NWT) is 66.9 years, which is comparable to the national average as it was in 1950 (Statistics Canada, 2005). Similarly, in regions with higher Aboriginal populations, the potential years of life lost due to all causes are much higher, and incidences of trauma and lifestyle-related cancers are greater (INSPQ, 2006) (Table 7.2). According to Wigle et al. (2005), children and youth in the Canadian Arctic, and particularly Aboriginal children, suffer from comparatively lower health status than children and youth in other Arctic countries and in comparison with the Canadian general population as well.

Photo Credits: Peter Langer

Differences in the common causes of death among Arctic Aboriginal populations exist when compared with the national or northern non-Aboriginal population (AMAP, 2002). All northern regions report much lower rates of death from cardiovascular disease, acute myocardial infarction and heart attacks than the national average (Statistics Canada, 2001a) (Table 7.3). However, northern populations report higher than national rates of mortality from causes such as lung cancer and unintentional injuries (accidents) associated with motor vehicle accidents and drowning. The latter is likely associated, in part, with the high level of dependence on various modes of transport (e.g. skidoo, four-wheel all-terrain vehicle, boat) for activities that are a strong part of livelihoods and traditions in these areas (i.e. hunting, fishing and gathering activities). More than 70% of northern Aboriginal adults report harvesting natural resources by hunting and fishing and of those, more than 96% do so for traditional and subsistence purposes (Statistics Canada, 2001a). Finally, significantly higher rates of mortality are reported from intentional self-harm (suicide) than other regions of the country and this is particularly the case in Nunavut (Statistics Canada, 2001a) (Table 7.3). This indicator of social stress is also supported by statistics of perceived low level of social support among individuals in some regions of the North (Statistics Canada, 2001b) (Table 7.6).

Table 7.6 Selected social and economic indicators for Canadian northern regions

Indicator	Canada	Yukon	NWT	Nunavut	Nunavik	Labrador*
Sense of high social support†	–	78.0	74.5	58.1	–	85.8
Sense of belonging to local community (very strong or somewhat strong)	62.3	69.3	72.3	80.9	72.0	87.6‡
Percentage of Census families that are lone female-parent families	15.7	19.8	21.0	25.7	35.5	15.5
Personal average income $ (in the year 2000)	29,769	31,917	35,012	26,924	23,215	28,478
Government transfer income as proportion of total % (2000)	11.6	8.6	7.3	12.9	17.0	10.2
% long-term unemployed (labour force aged 15 and over)§	3.7	6.0	4.8	11.2	8.7	9.3
% of population aged 25–29 that are high school graduates	85.3	85.4	77.5	64.7	52.7	83.9

* Data from the former Health Labrador Corporation, which provided services to all of Central, Western and Coastal Labrador, including Black Tickle and points north (this organization merged with Grenfell Regional Health Services in 2005 to form Labrador-Grenfell Health).

† Level of perceived social support reported by population aged 12 and over, based on their responses to eight questions about having someone to confide in, someone they can count on in a crisis, someone they can count on for advice, and someone with whom they can share worries and concerns. Source: Statistics Canada, 2003.

‡ Labrador-Grenfell Health region: Includes all of mainland Labrador.

§ Labour force aged 15 and over who did not have a job any time during the current or previous year.

Source unless otherwise indicated: Statistics Canada, 2001a (20% sample).

The pattern of general and comparative indicators of mortality between northern populations and the rest of Canada sheds light on possible vulnerabilities. It is important to acknowledge that mortality differs with geographic location and socio-demographic characteristics. Significantly more deaths occur from cancers and cardiovascular disease in the larger communities of the NWT, including Yellowknife, whereas in the smaller communities, intentional and unintentional injuries account for the largest proportion of deaths (22%) (Government of the Northwest Territories (GNWT), 2005). More than half of injury-related deaths and hospitalizations occur among individuals aged 15 to 44, whereas seniors have the highest injury-related deaths and hospitalization rates. Most injury-related deaths occur among males (78%); this is over three times the rate for females. The age-standardized injury-related mortality and hospitalization rates among Inuit and Dene in the NWT are more than twice as high as those among other residents (injury-related mortality: 179, 118 and 49 per 100,000, respectively; injury-related hospitalization: 2,576, 2,243 and 983 per 100,000, respectively) (GNWT, 2004).

Despite the territorial and provincial governments spending significantly more per capita on public health in northern regions, Northerners self-report poorer health status than elsewhere in the country (Statistics Canada, 2001b) (Table 7.2). Approximately half of Northerners in each region, slightly lower than the national average, report that their health is either "very good" or "excellent" (Table 7.4). When differentiating between Aboriginal and non-Aboriginal residents, there are further differences. For example, in the 1996 Census a much lower percentage of Aboriginal than non-Aboriginal people in the territories reported their self-assessed health as "high" (47% versus 69%) (Statistics Canada, 1998).

In terms of other key health behaviours, Northerners in general are more frequent smokers, have higher rates of obesity and alcohol consumption, yet report feeling less stress than the average Canadian (Statistics Canada, 2002). Approximately 80% of all Canadians had contact with a medical doctor in the year previous to the National Community Health Survey. This number was comparable in the Yukon (83%) and the region serviced by the Health Labrador Corporation (79%), but it was significantly lower in the NWT (71%) and Nunavut (53%) (Statistics Canada, 2001b). Contact with a doctor by Aboriginal residents was less than the non-Aboriginal territorial averages (59% versus 76%: Statistics Canada, 2002); however, contact with a nurse, who is often the primary health professional in small northern communities on a full-time basis, was much higher (Statistics Canada, 1998). The availability of general practitioners and specialists per capita is much lower in the territories than in other regions of the country (Statistics Canada, 2002). In general, Northerners are less satisfied with the health care they receive compared with the national average (84.9%), and the percentage of the population that are "very or somewhat" satisfied with the health care they receive decreases as one moves to the regions with a higher percentage Aboriginal population (Yukon, 85.3%; NWT, 81.6%; Nunavut, 74.2%) (Statistics Canada, 2004b).

7.2.5 Socio-Economic Status

Many northern community economies are now a mix of traditional land-based renewable resource and subsistence activities, and formal wage-earning sector activities often tied to non-renewable resource extraction. It is important to understand the economic capacity for adaptation at the household and regional or territorial levels in the North because it is a significant factor influencing the feasibility of local responses to minimize some forms of climate change impacts. A short description of economic activities, highlighting the nature of northern economic capacity and diversity at various scales, is provided in the text that follows.

Estimates of the "land-based" or traditional and subsistence economy are difficult, but are important to include in estimates of the gross domestic product (The Conference Board of Canada, 2005). The Conference Board of Canada estimated Nunavut's land-based economy to be worth between $40 and $60 million per year; an estimated $30 million is attributed to all food-oriented economic activity. Country foods[2] provide a non-cash or in-kind benefit in the amount of about $3.35 million annually in the ISR of the NWT alone or approximately $1,150 per capita. A typical household produces several thousand dollars' worth of food that it does not have to buy at the store (Smith and Wright, 1989; Usher and Wenzel, 1989). Tourism, which includes guiding, sport hunting camps and polar bear hunts, is estimated to be worth $4 million per year in Nunavut. However, the true value of such activities is difficult to measure because they also contribute significantly to the social, human and cultural capital of the region, and do not benefit people only in a monetary sense (The Conference Board of Canada, 2005). In general, fishing, hunting and trapping contributed $7.6 million to the wage-based gross domestic product of Nunavut in 1999. The traditional economy is similarly important in other northern regions (Duhaime et al., 2004).

2 While the terms "country food" and "traditional food" are used differently by different aboriginal groups within Canada, they have been used interchangeably for the purposes of this chapter.

Large-scale mineral resource extraction is central to the northern Canadian economy today. The NWT, Nunavut, Nunavik and Nunatsiavut are all home to major developments devoted to extracting minerals and hydrocarbon resources (Duhaime et al., 2004). While only a fraction of the revenue from these sources remains in the regions in which the activities are carried out, the employment directly associated with the activities represent significant benefits to the regions in terms of economic spin-offs in the form of related wage-earning employment for labour and infrastructure development; however, these benefits are typically only for the life of the project.

Geographic patterns of economic activity mirror the disparities in levels of personal income from region to region (Table 7.6). For example, in the NWT, workers in the mining industry receive high salaries resulting in a high regional per capita income in this region compared to others. On the other hand, in Nunavut, some of the higher paying jobs are in the government sector, and the overall regional average income is lower than elsewhere in Canada (Duhaime et al., 2004). Regional disparities in economic activity and personal income are important in the context of climate change because regional and community economies are significant factors that influence the capacity to adapt and minimize negative impacts. It is apparent that some regions likely have a greater economic ability to collectively respond to change than others.

For some climate change impacts, adaptation is likely to be most feasible at the individual or household scale, and thus economic disparities at these levels are also important to understand. In Nunavik, more than 55% of Inuit households live below the low-income threshold and represent more than 68% of the total population (Chabot, 2004). Longitudinal studies show that Inuit in Nunavik earn less than the non-Inuit working in this region; however, the gap is slowly narrowing (Duhaime et al., 1999). A similar pattern exists when looking at the sources of income and the amount that comes from government transfer payments. In Nunavut and Nunavik, a higher percentage of personal income comes from these transfers than other northern regions; thus, their economic capacity is more dependent upon outside sources than it is in other northern regions (Statistics Canada, 2001a) (Table 7.6).

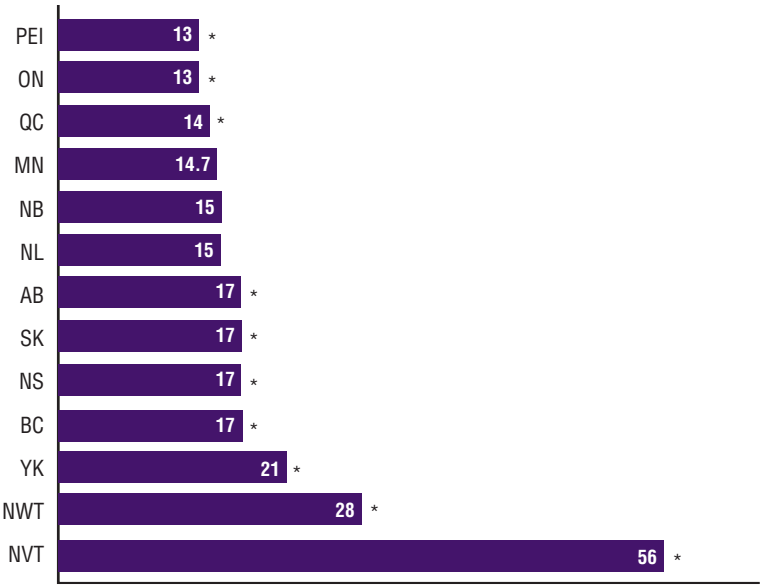
These socio-demographic, economic and health factors combine to create important issues for public and environmental health in northern regions. Individuals in some regions are challenged simply with the costs of access to adequate housing and food. For example, 80% of renters and 25% of home owners in Nunavik spend more than 30% of their household income on housing costs compared with national averages (39% of renters and 16% of home owners) (Statistics Canada, 2001a). Further, many Aboriginal residents have significant issues with the quality and safety of available housing. As of 2001, 28% of residents in Labrador, 68% in Nunavik, 54% in Nunavut, 35% in the NWT and 43% in the Yukon lived in overcrowded homes (Statistics Canada, 2001a; Council of Yukon First Nations (CYFN), 2006). Approximately 16% of homes in the NWT and 33% in the Yukon require major repairs, compared with the national average of 8% (Statistics Canada,

2001a; GNWT, 2005; CYFN, 2006). The housing issues are not uniform across the territories; problems (at least one of overcrowding, quality or affordability) are more often found among units in small communities (30%), compared with Yellowknife (9%) in the NWT (GNWT, 2005). Structural factors, social conditions and some health behaviours can combine to negatively influence the health of more vulnerable groups of the population in these regions. For example, Kovesi et al. (2006) identified potential risk factors related to poor indoor air quality for viral lower respiratory tract infections in infants living in Inuit homes on Baffin Island; these factors included reduced levels of air exchange, high occupancy and levels of environmental tobacco smoke exposure.

According to Ledrou and Gervais (2005), a "food insecure household" is one in which someone in the household had not eaten the quality or variety of food wanted, had worried about not having enough to eat or had actually not had enough to eat because of a lack of money in the year previous to their survey.

In Canada, 33% of female single-parent households and 21% of Aboriginal households are at risk for being "food insecure" or lacking "food security." Food insecurity is most common in the three territories where there are a significantly higher number of female single-parent households (Statistics Canada, 2001a; Ledrou and Gervais, 2005) (Table 7.6, Figure 7.4). The role of economics in this situation is critical in the North where the cost of a standard list of grocery items can be as much as three times more than that in southern locations (Statistics Canada, 2005) (Table 7.7).

Figure 7.4 Prevalence of food insecurity by province and territory compared with the Canadian mean



Data source: 2000/01 Canadian Community Health Survey

* Significantly different from estimate for Canada (P<0.05)

Source: Statistics Canada, 2005.

Table 7.7 Cost ($) of Northern Food Basket for selected northern and southern locations

Location	Perishables	Non-Perishables	Total Food Basket
Labrador and Nunatsiavut			
Nain, Nunatsiavut (2002)	90	106	196
Happy Valley-Goose Bay (2002)	64	82	146
Nunavik			
Kuujjuaq	92	129	220
Kangiqsujuaq	99	145	244
Nunavut			
Iqaluit (2005)	114	161	275
Pangnirtung (Baffin) (2005)	127	165	292
Rankin Inlet (Kivalliq)	153	165	318
Kugaaruk (Kitikmeot)	135	187	322
Northwest Territories			
Yellowknife	65	94	159
Deline	148	161	309
Tuktoyaktuk	129	154	282
Paulatuk	180	167	343
Yukon			
Whitehorse (2005)	64	99	163
Old Crowe	169	219	388
Selected southern cities			
St. John's, Newfoundland and Labrador (2003)	66	78	144
Montreal, Quebec (2005)	64	90	155
Ottawa, Ontario	72	93	166
Edmonton, Alberta	65	108	173

Note: Cost is for 2006 unless otherwise indicated. The Northern Food Basket is comprised of 46 items, based on Agriculture Canada's Thrifty Nutritious Food Basket used to monitor cost of a nutritious diet for a lower-income reference family of four (a girl 7–9 years, a boy 13–15 years, and a man and woman 25–49 years of age).

Source: Indian and Northern Affairs Canada (INAC), 2007.

The health and socio-economic information presented above illustrates some of the factors that need to be considered in assessing vulnerabilities to climate change and the geographical variability that has to be taken into account in a regional assessment of the North. Some trends are more uniform across regions such as the higher level of exposure to environmental risks among Aboriginal residents, largely based on their close relationship with the local environments that are an important part of their traditions, cultures, health and well-being (Berner et al., 2005). The smaller communities of the North with proportionately larger Aboriginal populations are likely to experience greater health vulnerabilities to climate change. Current knowledge of exposures and impacts, and documentation of existing adaptive responses will be further explored in subsequent sections.

7.3 NORTHERN HEALTH AND WELL-BEING: IMPACTS AND EXPOSURE TO CLIMATE CHANGE

The relationships between climate change and human health in northern populations are complex and often mediated through environmental, physical, social and behavioural factors. In a review of potential impacts on human health from climate change in Nunavik and Labrador, Furgal et al. (2002) reviewed medical and health sciences literature and conducted interviews with local experts (Elders, hunters, harvesters). They identified a list of direct and indirect relationships between health and climate for northern populations. Similarly, in the *Arctic Climate Impact Assessment,* Berner et al. (2005) took a mechanistic approach to the description and review of impacts on northern residents with a particular focus on Aboriginal populations. The review in this chapter adopts a similar approach. The direct impacts are considered "those health consequences resulting from direct interactions with aspects of the environment that have changed or are changing with local climate (i.e. resulting from direct interactions with physical characteristics of the environment: air, water, ice, land; and for example exposure to thermal extremes)" (Berner et al., 2005, p. 869). Following Berner et al. (2005), indirect impacts are "those health consequences resulting from indirect interactions mediated via human behavior and components of the environment that have changed or are changing with local climate" (p. 878). Data are presented in this section to provide an overview of the current state of knowledge on both direct and indirect impacts and exposures to climate-related variables across Canada's northern regions.

7.3.1 Direct Impacts of Climate Change and Variability

The direct impacts of climate on human health are primarily related to such phenomena as extreme precipitation events, climate-influenced natural hazards, uncharacteristic weather, extreme temperatures, and related injuries and stress (Table 7.8).

Table 7.8 Summary of potential direct climate-related health impacts in Nunavik and Labrador

Identified Climate-Related Change	Potential Direct Health Impacts
Increased (magnitude and frequency) temperature extremes	Increased heat- and cold-related morbidity and mortality
Increase in frequency and intensity of extreme weather events (e.g. storms, etc.) Increase in uncharacteristic weather patterns	Increased frequency and severity of accidents while hunting and travelling resulting in injuries, death, psychosocial stress
Increased ultraviolet radiation exposure	Increased risks of skin cancers, burns, infectious diseases, eye damage (cataracts), immunosuppression

Source: Adapted from Furgal et al., 2002.

7.3.1.1 Extreme precipitation events and natural hazards

Increased precipitation and warming temperatures have the potential to increase the risks of avalanches and landslides for communities and residents in mountainous regions of the North. Fatal avalanches and property damage have been recorded in Nunavik (Arctic Quebec), Nunavut, NWT and the Yukon previously. Following an avalanche in 1999 in the Nunavik community of Kangiqsualujjuaq that killed nine people and injured 25, the Ministère de la Sécurité publique du Québec (Quebec ministry of public security) conducted a review of avalanche risks and protective measures in 2000 (Lied, 2000). Topography, early winter

rain, freezing, heavy winds and snowfall on a crust of ice that allowed the destabilization of the snow mass were included among conditions reported as associated with this avalanche. Based on the analysis, a recurrence of the 1999 event every 50 years was estimated (Lied, 2000). Communities in Nunatsiavut and other regions have reported an increasing frequency of mid-winter thaw–freeze events that can create conditions conducive to avalanches (Communities of Labrador et al., 2005). Current model projections report the greatest warming during the winter in the eastern Arctic, accompanied by increased precipitation. However, regions of western Arctic are particularly vulnerable; communities most at risk are those in the mountainous regions of the Yukon where significant winter warming has already been experienced to date and significant increases in winter precipitation are projected for the future.

In summer and fall months, landslides are a concern on slopes where permafrost is melting and exposed to heavy rainfall. Communities in the ISR of the NWT and in Arctic Bay, Nunavut, have reported recent observations of such events for the first time in existing memory (Ford et al., 2006; Nickels et al., 2006). These events are reported to result in an increase in dangerous travelling conditions in these locations (Ford and Smit, 2004; Community of Arctic Bay et al., 2005; Barron, 2006; Ford et al., 2006).

7.3.1.2 Unpredictability of weather conditions

Aboriginal residents of small remote communities in all regions of the Canadian Arctic have reported that the weather has become more "uncharacteristic" or less predictable and, in some cases, that storm events progress more quickly today than in previous memory (Huntington et al., 2005; Ford et al., 2006; Nickels et al., 2006). Residents involved in these studies report that this unpredictability limits current participation in traditional and subsistence activities and travel; it also increases the risks of being stranded or involved in accidents out of reach of the community (Furgal et al., 2002; Ford and Smit, 2004; Ford et al., 2006; Nickels et al., 2006). In their community case study on vulnerability to environmental change in Arctic Bay, Nunavut, Ford et al. (2006) reported that "increased storminess" was said to increase the danger of summer boating and decrease access to some hunting grounds. These impacts have associated economic implications at the household level in terms of damaged equipment and decreased access to traditional food resources.

Motor vehicle (including snowmobile and four-wheel all-terrain vehicle) injury is currently a significant cause of death and hospitalization in the NWT and the Yukon, and more common among younger Aboriginal males living in small communities (GNWT, 2004; CYFN, 2006). However, whether these injuries are the result of accidents in the community or on the land, and whether or how many are associated with poor or unpredictable weather conditions is not known. There is some qualitative evidence to suggest that the incidence of accident-related injuries is increasing in smaller coastal communities that are located in already variable local environments (Nickels et al., 2006).

7.3.1.3 Temperature-related injuries

The greatest warming in the Canadian North is expected during the winter months, and more dramatic warming (above current regional norms) in the future is projected for the extreme northwest (Kattsov et al., 2005). Therefore, with decreases in mean winter cold temperatures, one might expect a reduction in cold-related injuries, such as frostbite and hypothermia, among all northern residents, particularly among those who are the most exposed (i.e. Aboriginal residents and others spending extended periods of time outdoors). In the Yukon First Nations Regional Health Survey, residents reported that 2%, 7% and 1% of injuries among adults, youth and children, respectively, were cold-related (hypothermia, frostbite or other) (CYFN, 2006). However, the relationship between exposure to cold and individual behaviours is more complex. For example, winter warming may be associated with increased weather instability; consequently, individuals may experience increased exposure to cold associated with storms and other hazardous conditions while out on the land. Therefore, a linear reduction in cold-related injuries may not be seen.

Some reports of respiratory distress on very hot days in the summer have been reported among Elders in Nunatsiavut and Nunavik in recent years (Furgal et al., 2002). Although current modelling of temperature extremes does not allow for a precise projection of the maximum temperatures to be expected, in northern Sweden, Messner (2005) identified a temperature rise of only 1°C to be associated with an increase in non-fatal acute myocardial infarctions by 1.5%. He proposed that this increase could be explained by a disruption in adaptation and a resulting increase in susceptibility to artherosclerotic diseases (Messner, 2005). The current rates of acute myocardial infarctions and cardiovascular-related deaths among all northern residents are comparatively lower than the national average in Canada (Table 7.5). However, cardiovascular and respiratory diseases in general are significant causes of mortality and hospitalization in many northern regions (GNWT, 2004). As the climate changes, ongoing fluctuations in the climate system are likely to result in new temperatures and extremes of heat; these will add to health-related stresses, and are likely to increase in frequency (e.g. summer daily temperatures greater than 30°C) (Kattsov et al., 2005).

7.3.2 Indirect Impacts of Climate Change and Variability

Indirect health impacts of climate change are primarily related to:

- changes in temperature influencing ice conditions;
- changes in exposure to animal-transmitted (zoonotic) diseases;
- changes in environmental conditions that influence the number of animals, human access to wildlife, and the health and quality of wildlife for human consumption (traditional food security);
- changes in exposure to food- and water-borne pathogens;
- melting permafrost which has implications for health infrastructure;
- changes in stratospheric temperatures and enhanced ozone depletion resulting in changes in human exposure to ultraviolet (UV) radiation; and
- the combined effects of environmental and other changes on social and mental well-being (Table 7.9).

Table 7.9 Summary of potential indirect climate-related health impacts in Nunavik and Labrador

Identified Climate-Related Change	Potential Indirect Health Impacts
Increased (magnitude and frequency) temperature extremes	Increase in infectious disease incidence and transmission, psychosocial disruption
Decrease in ice distribution, stability and duration of coverage	Increased frequency and severity of accidents while hunting and travelling resulting in injuries, death, psychosocial stress Decreased access to country food items, decreased food security, erosion of social and cultural values associated with country foods preparation, sharing and consumption
Change in snow composition (decrease in quality of snow for igloo construction with increased humidity)	Challenges to building shelters (igloos) for safety while on the land
Increase in range and activity of existing and new infective agents (e.g. biting flies)	Increased exposure to existing and new vector-borne diseases
Change in local ecology of water-borne and food-borne infective agents	Increase in incidence of diarrheal and other infectious diseases Emergence of new diseases
Increased permafrost melting, decreased stability	Negative impacts to stability of public health, housing and transportation infrastructure Psychosocial disruption associated with community relocation (partial or complete)
Sea level rise	Psychosocial disruption associated with infrastructure damage and community relocation (partial or complete)
Changes in air pollution (contaminants, pollens and spores)	Increased incidence of respiratory and cardiovascular diseases, increased exposure to environmental contaminants and subsequent impacts

Source: Adapted from Furgal et al., 2002.

7.3.2.1 Climate warming and ice safety

Both scientific studies and local observations report an increase in the length of the ice-free season, and a decrease in ice thickness and in total sea ice cover throughout the North (Huntington et al., 2005; Walsh et al., 2005; Nickels et al., 2006). Sea ice cover has decreased by 5 to 10% during the past few decades, as has multi-year ice cover and the thickness of sea ice in the central Arctic (Walsh et al., 2005). Earlier break-up and later freeze-up have combined to lengthen the ice-free season of rivers and lakes by up to three weeks since the early 1900s. Model projections show a continuation of recent trends throughout the 21st century, with sea ice retreat and summer sea ice loss projected to be the greatest in the Beaufort Sea (Walsh et al., 2005). Flato and Brown (1996) estimated that continued warming will decrease landfast ice thickness and duration of cover by approximately 0.06 m per 1°C and 7.5 days per 1°C, respectively. Ford et al. (2006) suggested that this could mean a decrease in thickness of 50 cm and in duration of coverage by two months by 2080 to 2100 for communities such as Arctic Bay, Nunavut.

The ice provides a stable travelling and hunting platform for many northern residents, and is critical to the reproduction and survival of some Arctic marine species (e.g. ringed seal, and polar bear) that are important for Aboriginal residents. Changes in the timing of the ice season and the security of this platform for human use are therefore critical for the safety

of northern residents that are active on the land, Aboriginal and non-Aboriginal alike. Inuit residents of northern communities report that the changes in ice characteristics increase the dangers of being on the land and decrease access to hunting areas and traditional foods (Riedlinger and Berkes, 2001; Huntington et al., 2005; Nickels et al., 2006) (see Section 7.3.2.4 on food security for greater detail). An increase in the number of accidents and drownings associated with changing ice conditions is reported in some communities (Barrow et al. 2004; Lafortune et al., 2004); however, no review of accident data has been conducted to confirm these trends to date. Nickels et al. (2006) and Ford et al. (2006) reported impacts to Inuit household economies related to loss of earnings from seal pelt or narwhal harvests, damage to equipment and loss of access to certain wildlife food resources.

Finally, Aboriginal residents in all northern regions report that these ice changes have had negative implications for social cohesion and mental well-being because they disrupt the regular cycle of traditional land-based activities and impact the sharing of traditional foods (Huntington et al., 2005). Similar impacts to participation in hunting and fishing activities, human safety, and social and cultural well-being are reported in association with the increases in uncharacteristic weather patterns (Berner et al., 2005; Huntington et al., 2005; Ford et al., 2006; Nickels et al., 2006).

7.3.2.2 Increased exposure to UV radiation

With increasing concentrations of atmospheric GHGs and the consequent trapping of more heat below the stratosphere, stratospheric cooling will occur. This is likely to increase the frequency and severity of episodes of stratospheric ozone depletion (Weatherhead et al., 2005). Ozone concentrations in the stratosphere influence the amount of UVB radiation reaching the Earth's surface. Therefore there is a relationship between GHG emissions, climate change and UV radiation. Despite international action to reduce and eliminate the use of ozone-harming chemicals via the Montreal Protocol, these substances remain in the atmosphere for long periods of time, and thus ozone repair is expected to take at least until the middle of the current century (De Fabo, 2005). Ozone depletion at polar latitudes peaks during late winter and early spring (Weatherhead et al., 2005), when significant outdoor activity occurs in Canadian Arctic communities. The potential human health effects of enhanced UV exposure are therefore important to consider in the context of projected climate change. Although current rates of skin cancers are low in northern regions, community residents have reported increased incidence of sun rashes, burns and snow blindness in recent decades and in regions where these ailments were not previously observed (Furgal et al., 2002; Huntington et al., 2005; Nickels et al., 2006). In humans, UV exposure has been linked to conditions such as melanoma, cataracts, immunosuppression and non-Hodgkin's lymphoma, among others. Data on the incidence and distribution of such conditions and their relationship to current levels of UV exposure among Arctic populations are lacking. However, they warrant attention considering the projections of low ozone and elevated UV reaching the Earth's surface for several decades into the future (Weatherhead et al., 2005). This is especially important for those northern residents frequently exposed to the sun for long durations, such as Aboriginal residents spending significant periods of time on the land hunting and travelling during the late winter and early spring.

7.3.2.3 New and emerging diseases

Climate warming during El Niño-Southern Oscillation events has been associated with illness in marine mammals, birds, fish and shellfish. These illnesses have included botulism, avian Newcastle disease, duck plague, influenza in seabirds, and a herpes-like virus epidemic in oysters. Consequently, it is likely that long-term temperature changes resulting from climate change will be associated with changes in the types and incidences of diseases and outbreaks in those species that can transmit disease to humans (Bradley et al., 2005).

Many zoonotic diseases currently occur in Arctic host species, such as tularemia in rabbits, muskrats and beavers; rabies in foxes (Dietrich, 1981); brucellosis in ungulates, foxes and bears; echinococcosis in rodents or canine species (Chin, 2000); trichinosis in walruses and polar bears; and cryptosporidiosis in both marine (ringed seals) and terrestrial mammals. Changes in the spatial occurrence of these diseases is likely because they are spread through temperature-mediated mechanisms, such as the movement of animal populations and contamination of surface waters used by Arctic populations.

El Niño-Southern Oscillation events are characterized by a decrease in western trade winds and sustained increase in sea surface temperature off the west coast of North and South America, resulting in a warmer and wetter climate for the Americas, typically lasting for 1 to 2 years.

The most common agents of food- and water-borne diseases in the NWT are *Giardia* (from drinking contaminated water) and *Salmonella* and *Campylobacter* (from contaminated foods, usually those that are unpasteurized, or are eaten raw or poorly cooked) (GNWT, 2005). Some regions have documented significant cases of zoonotic infections in the past. For example, since 1982, 11 outbreaks involving 86 confirmed cases of trichinosis have been documented in Nunavik. Walrus meat was the source in 97% of cases (Proulx et al., 2000), but no deaths have been recorded from the disease. Reported cases of *Campylobacter* and *Salmonella* have declined in recent years in the NWT (GNWT, 2005). However, an increase in parasites in caribou has been reported in the central and eastern Arctic in recent years, and local hunters have expressed concerns about the safety of the consumption of this meat (Nickels et al., 2006). Kutz et al. (2004) described the role that a combination of climate warming, shrinking habitats and changes in other ecological factors have played in the emergence of three nematode species in muskoxen in the central and western Arctic, one of which may be important in regulating population numbers of this species on Banks Island, Nunavut.

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Similarly, the over-wintering survival and the distribution of some insect species are increased by warming temperatures, and create opportunities for the introduction of new diseases into Arctic regions or increased risk from endemic pathogens (Parkinson and Butler, 2005). Insects are therefore likely to change in their distribution with warming in Arctic regions and increase the incidence of diseases among human populations (Bradley et al., 2005; Parkinson and Butler, 2005). Climate change may have already shifted the range of tick-borne encephalitis toward more northern latitudes (Rogers and Randolph, 2006). Studies suggest that increasing temperature will continue to favour further northward expansion of the geographic range of *Ixodes scapularis,* the tick vector of Lyme disease; temperature conditions suitable for this tick may occur in the NWT by the 2080s (Ogden et al., 2006). The spread of the spruce bark beetle and its contribution to increasing forest fire risk in the Yukon, and the potential impacts this has

for residents of that region is another example of how insect activity and climate change can be related to risks to humans (Furgal and Prowse, 2008). In the ISR of the NWT, where more warming has taken place in recent decades, residents have reported seeing increased numbers and new species of insects, including biting flies and bees (Barrow et al., 2004; Nickels et al., 2006).

No coordinated effort to date has examined and catalogued endemic and potential zoonoses in the Canadian North. The research that has been conducted to measure these zoonoses in a way that is likely to assess or monitor climate change effects is limited. Gosselin et al. (2006a, 2006b) are currently conducting a review of environmental health surveillance systems in the Canadian North, however the data for many zoonotic diseases in northern regions is not yet sufficient to allow a comparable assessment across the Arctic.

7.3.2.4 Food security

Food security is not only an issue of insufficient amounts of food but also access to enough safe and nutritious foods. It is an important determinant of health, cultural and social well-being, justice and dignity (McIntyre et al., 2003).

Yaro (2004, p. 23) defines food security as "secure access by households and individuals to nutritionally adequate food at all times and procured in conformity with human aspirations and dignity."

People who are "food insecure" (not achieving a status of "food security") are at increased risk of being overweight, and having chronic health conditions, mental health challenges and a lower learning capacity (McIntyre et al., 2003). In Canada, younger generations, women and Aboriginal people are most likely to report experiencing food insecurity (McIntyre et al., 2003; Ledrou and Gervais, 2005). Residents in the North are the most likely to report food insecurity at the household level, with the rate in Nunavut being four times higher than the national average (Statistics Canada, 2005) (Figure 7.4). In northern communities, the diet of many residents is a combination of imported foods from outside of the region and local foods harvested from the environment. Items from outside of the region are transported by air, by truck on seasonal or all-weather roads, by boat or by a combination of mechanisms. Thus, the food security of northern residents may be influenced by climate change through impacts to the access, availability or quality of locally harvested wildlife, or through impacts to transportation networks linking northern communities with southern sources of market foods.

Country/Traditional foods

Aboriginal residents maintain a strong and vital connection to the Arctic environment through traditional and subsistence activities of hunting, fishing and gathering a variety of animal and plant species. The traditional and cultural importance of these activities distinguishes them from other northern residents. Country food-related activities have crucial economic and dietary importance; they are also important in maintaining social relationships and cultural identity (Nuttall et al., 2005). Food items, collected from the land, sea, lakes and rivers, continue to contribute significant amounts of protein to the total diet, and help individuals to meet or exceed daily requirements for several vitamins and essential nutrients. In some instances, they protect individuals from some types of cardiovascular disease and contaminant toxicity (Blanchet et al., 2000; Kuhnlein et al., 2000; Van Oostdam et al., 2005).

Dietary survey work conducted throughout the North with Yukon First Nations, Dene, Métis and Inuit communities shows the extent of use of these foods on a regular basis (Table 7.10). In the Yukon, country food consumption contributed 50% or more of important nutrients such as protein, iron, zinc and vitamin B12 to First Nations residents' diets (Receveur et al., 1997). Recently, the Regional Health Survey (CYFN, 2006) reported similar results with most respondents (81% of adults, 72% of youth and 65% of children). Similar results were obtained in Dene and Métis communities in the NWT where country food consumption was found to contribute 144g/day to the total diet among women and 235g/day among men (Kuhnlein and Receveur, 2001). As well, on days that country foods were consumed, individuals' diets were healthier in terms of saturated fat, sugar and carbohydrate intake. Among Inuit residents in the NWT, Nunavut and Nunatsiavut, similar levels of intake and contribution to nutrient and energy intake were reported. The contribution of these foods to total energy intake ranges from 6% in communities close to regional centres up to 40% in more remote communities (Kuhnlein and Receveur, 2001). However, despite their significant importance, northern populations are shifting away from country foods and increasing the amount of store-bought food stuffs in their diet, as is being experienced in many other Aboriginal populations (Kuhnlein, 1992; Wein and Freeman, 1992). This is especially the case for younger people and in those communities with greater access to store-bought foods (Receveur et al., 1997). This shift is resulting in an increased intake of carbohydrates and saturated fats, and is projected to change the incidence of western-type diseases among this population in the future (e.g. increased incidence of obesity, diabetes and heart disease).

Table 7.10 Five country food items most often consumed (yearly average of days per week)

Population*	Food item and yearly average of days consumed per week				
Yukon	Moose 1.6	Caribou 0.7	Salmon 0.6	Grayling 0.4	Trout 0.1
Dene and Métis					
Gwich'in	Caribou 3.2	Whitefish 1.3	Coney 0.5	Moose 0.3	Scoter 0.2
Sahtu	Caribou 2.5	Moose 1.0	Trout 0.8	Whitefish 0.7	Cisco 0.3
Dogrib	Caribou 3.9	Whitefish 1.2	Trout 0.2	Moose 0.2	Walleye 0.2
Deh-cho	Moose 2.7	Whitefish 0.9	Caribou 0.8	Spruce Hen 0.4	Pike 0.3
South-Slave	Moose 2.2	Caribou 1.9	Whitefish 1.8	Trout 0.4	Ptarmigan 0.2
Inuit					
Inuvialuit	Caribou 1.8	Char 0.5	Goose 0.2	Whitefish 0.2	Muskox 0.1
Kitikmeot	Caribou 1.2	Char 0.9	Muskox 0.3	Trout 0.3	Eider Duck 0.2
Kivalliq	Caribou 1.9	Char 0.4	Crowberry 0.2	Beluga Muktuk 0.2	Trout 0.1
Baffin	Caribou 1.3	Seal 1.0	Char 0.9	Narwal Muktuk 0.2	Beluga Muktuk 0.1
Labrador (Nunatsiavut)	Caribou 1.3	Trout 0.5	Partridge 0.3	Cloudberry 0.3	Char 0.2

* For each population, food items are listed in decreasing order of frequency of consumption from left to right.

Source: Adapted from Kuhnlein et al., 2002.

Climate change poses a threat to country food security in northern regions because it influences animal availability, human ability to access wildlife, and the safety and quality of wildlife for consumption. Decreased access to winter forage (lichen and other vegetation) as a result of harsh winter weather—including heavy snow events and increased icing associated with temperature variability, and winter occurrence of freezing rain—is reported to be associated with significant animal die-offs and a steep decline in the populations of some central and western Arctic caribou herds (Miller and Gunn, 2003; Harding, 2004; Gunn et al., 2006; Tesar, 2007). Declines have been so severe in recent years that managers are contemplating limiting the non-resident and non-Aboriginal harvest, to protect herds and support recoveries (Tesar, 2007). Residents from

both the Yukon (Beaver Creek) and the NWT (Deh Gah Got'ie First Nation, Fort Providence) communities are witnessing changes in climate that are affecting the availability of species and residents' ability to access and harvest them, and hence likely their nutrient intake from these traditional foods (Guyot et al., 2006). In some cases, residents are already having to shift or adapt harvesting activities and reduce their consumption of some species, and in other cases, they are able to increase their take of other animals that are moving into their region and becoming more common. Work conducted by Riedlinger (1999), Furgal et al. (2002), Ford et al. (2006), Nickels et al. (2006) and others, with Inuit residents throughout the North, report similar results.

Lower water levels in rivers and ponds in Labrador were reported to negatively impact access to and health of fish species (Furgal et al., 2002; Communities of Labrador et al., 2005). Higher winds around Nunavut and Nunavik communities were reported to make travel and hunting more difficult and dangerous by boat in the summer; therefore, opportunities for hunting seals and whales in open water were limited (Ford et al., 2006; Nickels et al., 2006). In the ISR, Nunavut and Nunavik, the increased length of the ice-free season and decreased ice thickness resulting from warming winter temperatures was reported to reduce, and make more dangerous, access to ice-dependent wildlife species (e.g. ringed seal and polar bear) and other species commonly hunted from the ice (e.g. narwhal) (Ford et al., 2006; Nickels et al., 2006). What these and other climate-related impacts to food availability and accessibility mean in terms of shifts in per capita consumption of wildlife species nutrient intake throughout Arctic communities is currently a topic of significant study.

In addition to providing significant health benefits, country food species are the most significant source of exposure to environmental contaminants, such as polychlorinated biphenyls, mercury and lead, for northern residents (Van Oostdam et al., 2005). The uptake, transport and deposition of many of these contaminants are influenced by temperature. Therefore, climate warming is likely to indirectly influence human exposure to these contaminants which, among other effects, are known to adversely affect immune and neuromotor functioning in children (AMAP, 2003; Després et al., 2005; Kraemer et al., 2005). Booth and Zeller (2005) reported that projected climate warming in the North Atlantic (0.4–1.0°C) over the current century will increase rates of mercury methylation and hence concentrations in marine species between 1.7% and 4.4%. These increases could have implications for human exposure via consumption of some fish and marine mammals in these regions. Developing fetuses and young mothers are those most vulnerable to contaminant exposure (Van Oostdam et al., 2005). Currently, levels of exposure to mercury and other contaminants among some segments of the population in Nunavik and Nunavut exceed Canadian and international safety guidelines; advisories or consumption advice attempt to limit exposure (Van Oostdam et al., 2005).

Market foods

The consumption of market foods varies among and within regions, communities and households. For example, in Nunavik, the NWT and the Yukon, market foods contribute a lower proportion of the total diet among Aboriginal residents, older age groups, and those residents living further from a regional centre (e.g. Yellowknife, Whitehorse or Kuujjuaq) (Blanchet et al., 2000; Kuhnlein et al., 2000; Van Oostdam et al., 2005). Currently, the consumption of

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recommended levels of market items such as fruit and vegetables is considerably lower among northern residents than the national average, and is lowest among residents of Nunavut (Statistics Canada, 2005). In the NWT, males and older individuals were less likely to "eat well," as defined by *Canada's Food Guide to Healthy Eating,* than others (GNWT, 2005). However, a significant portion of total daily energy intake still comes from market food items in both Aboriginal and non-Aboriginal diets across the North, and access to safe, healthy and nutritious market foods are important for growth and development.

Changes in critical transportation infrastructure throughout the North may influence the transportation of market food, and thus affect its access and affordability in small, remote communities where many items are already prohibitively expensive (Table 7.7). Climate warming and warming of permafrost have negative implications for ice roads, all-season roads, and airstrip security and accessibility. Regional representatives to a Transport Canada (2003) workshop on climate change and transportation reported that some significant impacts to transportation infrastructure were already present. Work by Allard et al. (2002) in Nunavik, which has no road network, reports the instability of airstrips as a result of current permafrost warming. Conversely, a longer open-water season with decreasing sea ice coverage and extent will provide greater boat access to coastal communities throughout the year, and make ship and barge transportation more viable. Additionally, warming temperatures may increase opportunities for local food production in some regions, alleviating the potential stress of relying on transportation networks with the south. Increased summer temperatures and growing periods in regions such as the western Arctic may enhance opportunities for small-scale northern agriculture; these may provide an additional and potentially more cost-efficient local source of foods than other sources that are often expensive and difficult to access in these northern regions. Mills (cited in IPCC, 2001), for example, identified significant areas (39–57 million hectares) of potentially viable land for northern agriculture in the western Arctic under future climate scenarios.

As a result of the complexities in understanding trends and potential climate influences on changes in total diet (both traditional and market foods), the combined effects of climate change on food security and health are difficult to predict. They are influenced by local availability and access factors, including economic, technological and political forces. They also presuppose a strong understanding of what the local environment can provide and sustain in the way of wildlife and other food resources.

7.3.2.5 Water security

Although the Arctic is dominated by water either as ice, precipitation or in its many bodies of surface water, there is significant evidence that climate change is affecting and will continue to impact the quantity and quality of freshwater resources in the North (Walsh et al., 2005). Northern residents have already expressed concern about the quality of water in their communities during the 2001 Aboriginal Peoples Survey. The number of Inuit residents who feel their drinking water at home is unsafe to consume ranged from 9% (Labrador) to 43% (Nunavik). In the Yukon, 25% of First Nations residents reported that their water was unsafe for consumption (CYFN, 2006). In the Sierra Legal Defence Fund's (2006) drinking water report card for Canada, the northern territories ranked with some of the lowest regions in the country in terms of adoption and implementation of standards, testing criteria, certification requirements for water plant operators and public communication protocols. However, the incidence of *Giardia* in the NWT appears to be decreasing (from 4.7 cases per 10,000 in 1991 to 2.9 cases per 10,000 in 2002) whereas the incidence of *Escherichia coli* has remained comparatively the same over this period (GNWT, 2005).

In northern communities, water is transported and stored for household use through a number of different means. Water is taken from a local lake or reservoir at higher elevation than the town site and delivered by gravity to homes; delivered through an above-ground piping system (utilidor system) to and from a treatment facility (a few NWT and Nunavut communities); delivered by truck to individual households and stored in tanks (as in most northern villages); or collected and brought to the house using an individual bucket-haul system (Fandrick, 2005). In one of the few studies of drinking water in northern communities and their vulnerability to environmental change to date, Martin (2005) reported that approximately 30% of the Nunavik population chooses to use raw or untreated water directly from a natural source, such as a local stream or brook, for daily household use. In the Yukon, this number is 2% of the First Nations population (CYFN, 2006). In their examination of various water sources in and around 14 Nunavik communities, Martin et al. (2005b) reported that water currently held in household tanks was of good microbiological quality and safe to drink. On the other hand, samples of untreated water taken from natural local sources, which are then often stored in plastic containers inside many homes, were frequently contaminated. Plastic containers used to hold water inside the house were contaminated more frequently than proper household reservoirs. Commonly used natural sources for drinking water around the community were tested and found to have had counts of both *Escherichia coli* and *Enterococcus* that exceeded limits for safe drinking (≥1 per 100 ml). Martin et al. (2005b) reviewed the history of potential water-borne diseases in Nunavik (Table 7.11) and outlined the possible impacts that a changing climate may have on water sources, distribution and storage methods. Climate-related changes influence the quantity, quality and accessibility of drinking water resources, predominantly in smaller remote northern communities (Moquin, 2005). Prioritization of water use is required when the availability of safe, uncontaminated water is limited. Clean water is essential for drinking and cooking; if supplies are limited, water for maintaining a hygienic environment may not be available, thus providing a situation that is conducive to the spread of infectious illness.

Table 7.11 Oberved and likely water-borne diseases in Nunavik (1990–2002)

Disease	Agent	Declarable Disease	Total Number of Cases 1990–2002
Giardiasis	*Giardia duodenalis* (P)	X	52
Salmonellosis	*Salmonella* spp. (B)	X	18
Amebiasis	*Entamoeba histolytica* (P)	X	2
Campylobacteriosis	*Campylobacter* spp. (B)	X	14
Enterovirus meningitis	Several enteroviruses (V)	X	12
Gastroenteritis *(Escherichia coli)*	Enterotoxigenic *E. coli* (B) Enterohaemorrhagic *E.coli* (B)	X	2
Hepatitis A	Hepatitis A (V)	X	1
Shigellosis	*Shigella* spp. (B)	X	240
Typhoid fever	*Salmonella typhi* (B)	X	1
Norwalk virus infection	Norwalk virus (V)		
Cryptosporidiosis	*Cryptosporidium parvum* (P)		
Helicobacter gastritis	*Helicobacter pylori* (B)		
Toxoplasmosis	*Toxoplasma gondii* (P)		

Note: P, protozoan; B, bacteria; V, virus; x, disease is declarable.

Source: Martin et al., 2005a.

Researchers collecting local observational accounts from northern community members have described reports of increasing temperatures in the western Arctic that are supporting increased algal and plant growth in waterways, which in turn impacts drinking water quality and quantity (Barron, 2006; Nickels et al., 2006). Residents in the eastern Arctic have observed shifts in precipitation regimes that are reported to impact water quality. In some regions, communities have reported impacts to the availability and quality of water used for specific purposes and at certain times of the year.

7.3.2.6 Permafrost, coastal erosion and community infrastructure

Permafrost underlies more than 40% of Canada's land surface. Half of this area contains permafrost that is warmer than -2°C and therefore is sensitive to fluctuations in average temperatures; as a result, this permafrost is expected to be impacted under current climate model projections (Smith et al., 2003) (Figure 7.5). The northwest Canadian Arctic is particularly sensitive because significant warming has already occurred in upper layers of permafrost in that region (Burn, cited in Couture et al., 2003). Brown et al. (2000) and Allard et al. (2002) reported that upper layers in the Ungava region of Nunavik have now also increased in temperature by up to 2°C since the mid-1990s. Because of the combined forces of sea level rise and coastal erosion, as well as permafrost melting and ground instability—infrastructures in communities located in low-lying coastal areas, and constructed in high permafrost risk thaw zones, are most vulnerable to climate change. Nelson et al. (2002) identified communities in the northwestern Canadian Arctic (Mackenzie Delta) as being most "at risk" for impacts to infrastructure. The implications are significant for infrastructure, such as wastewater treatment and distribution networks, water distribution systems relying on pipe systems, basic housing, and emergency transportation access routes for remote isolated communities; the effects of climate change on infrastructure will have impacts on human health (Warren et al., 2005).

"Freshwater is not as good anymore. It tastes swampy because it is not moving as it should. The water flow in creeks is much less now...Some drinking water sources are not there now."

(Resident, Community of Tuktoyaktuk et al., 2005)

"When it does rain, and it rains a lot, then the water quality is affected by bacteria etc. The water quality is getting worse and worse every year and there are more and more boil water warnings."

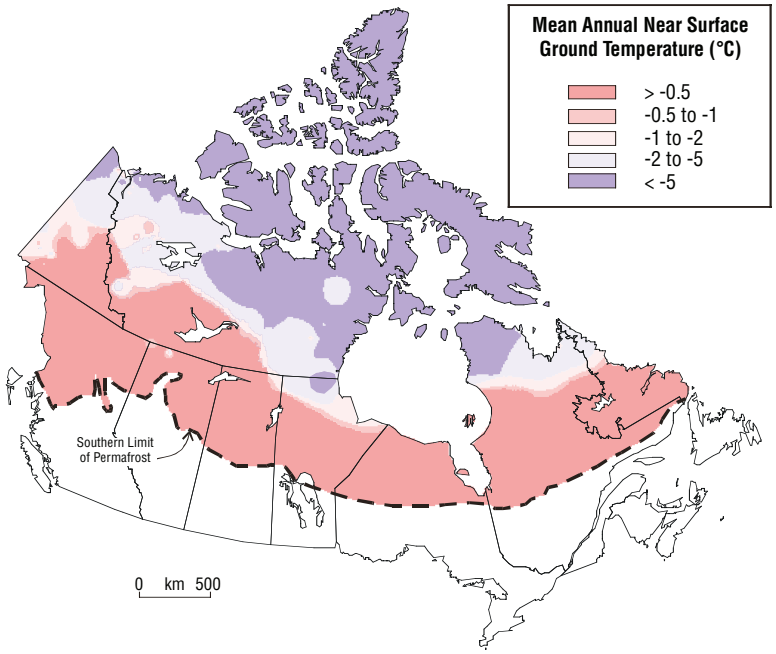
(Resident, Community of Kangiqsujuaq et al., 2005)

"The glaciers, which used to reach right into the sea, have all receded, some to the point that you can no longer see them. Permanent snow, which used to remain in the shady areas has started to melt and is no longer available for water in the summer...the Inuit really depend on this water for their tea."

(Pijamini, NTI Elders' Conference, 2001)

Photo Credits: Eric Loring

Figure 7.5 Spatial variation in mean annual near-surface ground temperature for the Canadian permafrost zone



Note: Within the zone classified as having temperatures >-2°C, regions with permafrost will have ground temperatures <0°C (Smith et al., 2003).

Source: Smith and Burgess, 2004 unless otherwise indicated.

Some communities in the western Arctic have already begun to report impacts to community buildings from these combined forces of erosion and permafrost melting (Communities of the ISR et al., 2005). Residents have reported concern and distress related to impacts to important cultural sites, housing and the potential relocation of communities in the future (Barrow et al., 2004). In the eastern Arctic, concerns about high water and erosion have also been recorded to date (Furgal and Prowse, 2008).

"People watch for erosion and have to move their cabins back from the river."

(Aklavik resident, Community of Aklavik et al., 2005)

"Long spits and points around the community are gone and it is predicted that the Hamlet office we are in now will be an island in 40 years."

(Tuktoyaktuk resident, Community of Tuktoyaktuk et al., 2005)

Bradley (2005) argues that many northern communities are more vulnerable to the acute impacts of climate change because they are isolated and lack transportation and an emergency response infrastructure. The degradation of permafrost has impacted key transportation infrastructure, which is an important part of emergency response capacity (Warren et al., 2005). This is particularly important in remote locations with few access routes and available means of transportation, such as communities that are accessible only by air or water for medical evacuations (e.g. all communities in Nunavik, Labrador north coast, Nunavut). Deformation of an airstrip because of permafrost warming, documented in Tasiujak, Nunavik, is more important than it would be in less isolated communities (Allard et al., 2002). Continued warming, combined with permafrost melting and sea-level rise, are expected to continue to impact infrastructure in the Arctic.

7.3.2.7 Mental, social and cultural well-being

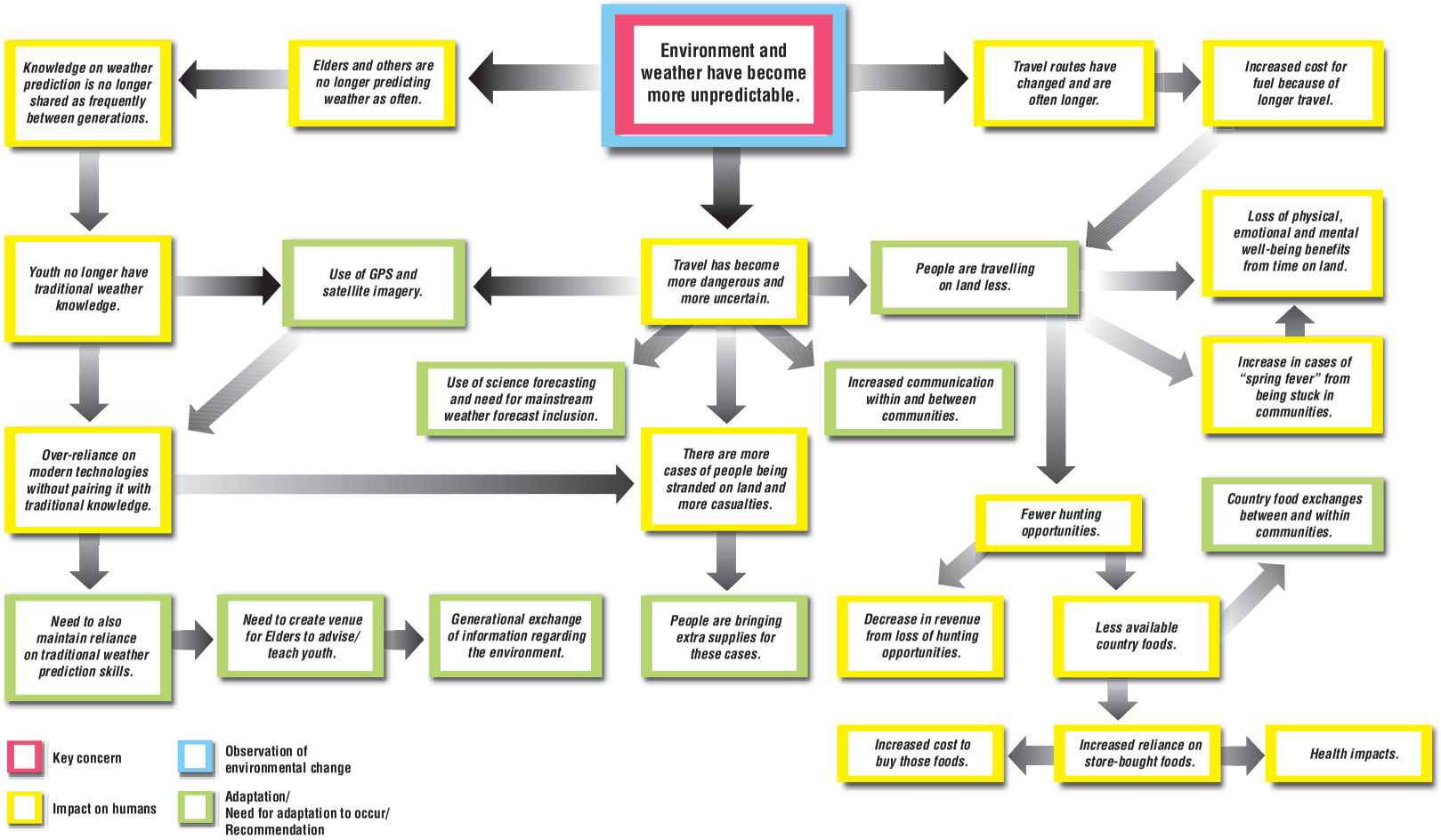
Many of the impacts described earlier in the text, on their own, or in concert with one another, represent forces of change to many northern residents for whom the connection with the local environment is a strong component of their mental health, culture and identity. Berner et al. (2005) and Curtis et al. (2005) described climate change and other forms of environmental change in northern communities as a force involved in the acculturation process of Aboriginal residents. For many remote northern communities, environmental change interacts with overall socio-cultural and economic processes that influence psychosocial, mental and social distress, such as alcohol abuse, violence and suicide. Rates of suicide are significantly higher in northern regions that have a higher Aboriginal population, and these numbers are particularly influenced by rates among Aboriginal youth, which in some regions have continued to rise (Government of Canada, 2006) (Table 7.2).

The impacts of climate change already being observed in some northern communities include the disruption of traditional hunting cycles and patterns in Arctic Bay (Ford et al., 2006; Nickels et al., 2006), loss of the ability of Elders to predict weather and provide information to hunters and other community residents (e.g. Community of Kangiqsujuaq et al., 2005), coastal erosion and damage to and loss of sacred sites and infrastructure (e.g. cemeteries and homes) (Community of Tuktoyaktuk et al., 2005). These impacts have implications for cultural, social and mental health, mainly among northern Aboriginal residents for whom the connection to the local environment is so important. As Owens (2005) reported from work conducted with Inuit women in Nunatsiavut, the ability to go on the land, travel, hunt, fish or collect berries and be safe outside of the community is a critical determinant of health for Inuit. This is because it provides the connection with the land, is an important source of physical activity, brings individuals together and is an important part of reconnecting with Inuit identity, transmitting language and knowledge, and relieving physical and mental stress associated with community-based jobs. Currently, little work has been done throughout the regions of the Canadian North examining the importance of environmental accessibility and stability, and its relationship to health status.

7.3.3 Multiple Stressors, and Health and Well-Being: Climate, Culture and Socio-Economic Change

Health is a multi-faceted concept, influenced by a variety of determinants, one of which being the physical environment; climate change is one of many environmental factors that make up the physical environment. The relative importance of different factors in determining health in the North is still not well understood. Climate change and variability may interact in one of a number of ways with other key driving forces present in a region. For example, a driving force (e.g. cultural change and shifts away from the consumption of country foods) may be enhanced by climate change (e.g. climate variability is making access to country foods more difficult and enhancing the existing decline in consumption of these foods). Climate change may act synergistically with other determinants as in the example of the impact of water temperatures on Greenland shrimp and cod fishing and resultant changes in mental and social health in Greenland communities (Hamilton et al., 2003; Curtis et al., 2005). Finally, climate and other factors or determinants may interact in a way that lessens the potential impacts of climate on health or provides new opportunities to improve health and well-being (e.g. increasing access to new wildlife species moving further north). Aboriginal residents recognize and have reported these links between aspects of climate change, shifts in environmental components, and implications for their health and well-being; most report a net negative effect on an individual scale (Figure 7.6). In recognizing these relationships, it is important to consider climate as one of many determinants in northern regions influencing human health and to try to understand the complexity of the context within which it is acting.

Figure 7.6 Relationships among increasingly uncharacteristic weather conditions, human impacts and responses as reported by Inuit participants at community workshops on climate and environmental change in the Canadian North



Source: Adapted from Nickels et al., 2006.

Chapin et al. (2005) stressed the importance of considering the synergies and trade-offs among the many forces at play within the context of climate, culture, development and health and well-being in polar regions when looking at the impacts of any factor or determinant. The increased growth of the wage economy in regions of the NWT associated with mining, for example, reduces the necessity and time available to participate in hunting and fishing activities on the land. This in turn reduces the transmission of traditional knowledge and environmental respect to younger generations, as well as the health benefits from the consumption of local foods. However, at the same time, access to the cash economy can also provide resources for the purchase of hunting equipment (e.g. boat, all-terrain vehicle, skidoo), supporting the ability to hunt more species and access a larger area. The purchase and adoption of newer technologies, such as global positioning systems (GPS), used for travel and hunting increases safety in some circumstances, but may also lead to individuals taking greater risks on the land and increasing exposure to otherwise avoided hazards (Ford et al., 2006).

Climate warming in the central Arctic and the resulting decrease in sea ice cover and extent are projected to increase access to, and navigability of, the Northwest Passage over the coming decades (Furgal and Prowse, 2008). If, as expected, marine traffic increases, new threats will be introduced to northern regions (e.g. spread of new and exotic species and diseases, increased risk of marine accidents such as oil spills) (Kelmelis et al., 2005). Traditional lifestyles of northern residents are likely to be significantly affected by both the loss of ice and increased shipping activity. The development of a deep-sea port at Bathurst Inlet, which is more economically feasible under a reduced ice scenario, will mean enhanced opportunities for mineral exploration and development throughout the interior regions of mainland Nunavut and the eastern NWT (Slave Geological Province). This could have both positive and negative impacts on health in those regions, as has been experienced in the NWT in association with the development of diamond and other mineral projects (GNWT, 2005).

After reviewing key determinants of health and their interactions in the circumpolar North, Chapin et al. (2005) reported that the deterioration of cultural ties to traditional and subsistence activities (and all that they represent) is the most serious cause of decline in health and well-being among Aboriginal people in Arctic regions. The disassociation of people from the land related to changes in lifestyle, loss of language, and dominance of non-Aboriginal education systems is impacting health and well-being in numerous and long-lasting ways. Similarly, significant and rapid changes due to large-scale industrial developments (e.g. establishment or closing down of a mine (GNWT, 2004)), the establishment of a new public administrative structure and organization (e.g. establishment of the territory of Nunavut) or the introduction of new telecommunications technology increasing access to outside regions (e.g. introduction of broadband Internet, or television) can play significant roles in the lives and livelihoods of all northern residents.

Photo Credits: Peter Langer

Because climate change is taking place in the context of a number of rapidly changing social, cultural and natural conditions, more knowledge is needed about the interactions among climate and other major factors of change in the Canadian North and how Northerners and, in particular, Aboriginal populations, are able to adapt to these changes. In Northern Canada, climate change, contaminants, remoteness, economic development, the capacity of the health system, and the training and retention of health care professionals all impact health outcomes (Public Health Agency of Canada (PHAC), 2006). A vulnerability framework recognizing multiple factors can help explore these interactions and help the understanding of impacts on and abilities of individuals and groups to adapt (WHO, 2003) (see Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada).

7.4 NORTHERN HEALTH AND WELL-BEING: ADAPTATIONS AND ADAPTIVE CAPACITY

7.4.1 Adaptations

Many climate-related changes have the potential to influence human health and well-being, and to place new stresses on the northern health sector. However, some of the resulting impacts on human health are avoidable—as shown by existing adaptation strategies employed at individual and collective scales in northern communities to minimize exposures to and impacts of environmental changes that are already taking place (Ford et al., 2006; Nickels et al., 2006). Although many countries are taking actions to immediately reduce greenhouse gas emissions, the trend toward a changing climate in the short term is already unavoidable. Therefore, it is necessary to consider strategies to adapt, especially in rapidly changing and vulnerable regions such as the Canadian North. Within the context of human health, the process of adaptation consists of the actions taken (including public health actions, policies and strategies) to minimize the negative health impacts of climate change (Health Canada, 2002). These actions can take a variety of forms (e.g. behavioural, institutional, technological, economic) and be primary, secondary or tertiary in nature (McMichael and Kovats, 2000). The ability to adapt, or the adaptive capacity of individuals or collective groups, is influenced by factors such as access to economic resources, technology, information and skills, institutional arrangements, public health infrastructure, equity among members of a group, and the existing burden of disease (see Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada).

The uncertainties associated with the potential effects of climate change, and the interactions with and influences of other forces of change in the North, make the development of possible adaptation strategies particularly challenging. Understanding of the magnitude and scope of the changes ahead, and impacts to health and well-being these changes represent at the local and individual scales, is still developing. The geographic size and ecological, cultural, socio-economic and demographic diversity (see Section 7.2) of the Canadian North mean that the nature and severity of projected impacts differ significantly among locations (Government of Canada, 2001). As a result, a diverse range of adaptive strategies may be required to best respond to the exposures and potential impacts from one region to another.

Adaptation can occur at the individual, collective, institutional or systems level, locally, regionally or nationally (Government of Canada, 2001). Currently, there are few examples of documented adaptations to the health impacts of climate change in the Canadian North. As well, there is some debate about whether changes in response to local environmental changes are in fact specifically "adaptations to climate change" or rather coping strategies for variable environmental changes that have been part of successful social and human evolution in this region for hundreds if not thousands of years (Berkes and Jolly, 2001). The few studies done to date on climate change impacts and individual and collective responses have focussed predominantly on remote Aboriginal populations.

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Consequently, there is more information about adaptation among these segments of the population and in these locations than there is about people living in larger population centres in the North or among non-Aboriginal residents. Currently, knowledge of current or future adaptations and adaptive capacity of northern non-Aboriginal residents is very limited, although there are some examples of adaptation strategies at the community and municipal scales (Government of Nunavut, 2006). Workshops and research projects conducted with Aboriginal residents (Riedlinger and Berkes, 2001; Nickels et al., 2002; Parlee et al., 2005; Ford et al., 2006) report that individuals are already, primarily in a reactive sense, adapting to minimize health-related impacts of climate change in the Canadian North. For example, workshops in the ISR of the NWT identified a number of actions individuals are taking in response to observed changes, and how these actions are affecting their livelihoods in their coastal communities (Table 7.12). A review of reported adaptive actions relevant to the health impacts of climate change are summarized in Table 7.13, and discussed briefly in the text that follows.

Table 7.12 Examples of environmental changes, effects and coping strategies/adaptations reported by community residents in the Inuvialuit Settlement Region to minimize negative health impacts of climate change

Observation	Effect	Adaptation
Warmer temperatures in summer	Not able to store country food properly while hunting, food spoils faster, less country food consumed	Travel back to community more often in summer while hunting to store food safely (freezers) *Need:* Investment for hunting activities Decrease amount and frequency of hunting *Need:* Reinvestment in support for community freezer programs
Warmer temperatures in summer	Can no longer prepare dried and/or smoked fish in the same way ("it gets cooked in the heat") Less dried and smoked fish eaten	Alter construction of smoke houses: build thicker roofs to regulate temperature Adapt drying and smoking techniques
Lower water levels in some waterways	Decrease in sources of good natural (raw) drinking water available while on the land Increased risk of water-borne illness	Bottled water now purchased and taken on hunting trips
More mosquitoes and other new biting insects	Individuals are bitten more Increasing public concern of health effects of new biting insects not seen before	Use insect repellent, lotion or sprays Use netting and screens for windows and entrances to homes *Need:* Public education on insects and biting flies to address perceptions and fears
Changing animal migration routes and times	Hunting more difficult (requires more fuel, gear and time) Some residents (e.g. Elders) cannot afford to go hunting and have less access to country foods	Initiation of community country food support programs for storage and distribution *Need:* Financial and institutional support to establish and manage these programs

Source: Adapted from Nickels et al., 2002.

Table 7.13 Summary of current responses taken by individuals and communities in the North, as reported in the literature, assisting in their adaptation to climate change and variability

Environmental Change and Impacts and Threats to Health and Well-Being	Existing Responses
Precipitation extremes and natural disasters • Property damage, injuries and death, increased travel risks	• Relocation of buildings in avalanche hazard zones • Increased needs for local search and rescue teams
Unpredictability of weather • Limitations on hunting and travelling • Increased travel risks and injuries • Increased damage to equipment • Decreased access to traditional foods	• Increased use and dependence on built (shelters) and natural (protected bays) refuges from storms • Increased communication among hunters • Increased preparations for travel and hunting • Decreasing outings during variable times • Use of technology (e.g. GPS)
Temperature-related injuries • Changes in incidence of cold-related injuries • Increased heat stress	• Reduce physical activity • Increasing house ventilation and accessing cool areas
Warming temperatures and changing ice conditions • Increased travel risks • Increased injuries and deaths (e.g. drowning) associated with uncharacteristic and dangerous ice conditions • Impacts to equipment and household economies • Decreased access to traditional food • Disruption of traditional cycles and impacts on social cohesion and mental well-being	• Shifting hunting patterns (e.g. times) • Using multiple means of transportation for same trip • Increasing community monitoring and communication of ice conditions • Use of new or alternate routes of travel • Use of technology (GPS, satellite imagery)
Increased exposure to UV radiation • Increased incidence of sun burns, rashes and blisters	• Increased use of protective creams • Stay out of sun and indoors
New and emerging diseases • Increased incidence and exposure to zoonotic diseases • Increased exposure to new vectors	• Increased use of insect repellents and bug nets • Increased selectivity of animal meat consumed (to screen for parasites and other abnormalities)
Environmental changes and food security • Decreases in traditional food availability (wildlife health and numbers), accessibility (changes in ice and snow conditions impacting routes to hunting grounds) and quality (safety of meat for consumption) • Appearance of new species • Increased potential for local-scale northern agriculture	• Changes in times of hunting (to match shifts in availability) • Shifting species hunted (to match changes in availability) • Purchase of new transportation equipment to access animals harder to reach • Return to community in summer more often from hunting trips to store fresh meat
Water security • Decrease in availability and accessibility to safe natural drinking water sources	• Carry bottled water on trips from the community • Use snow more often for water in winter than multi-year ice • Travel further from community for good natural water sources
Permafrost, coastal erosion and community infrastructure • Loss of land along shorelines near buildings • Destabilization of foundations and threats to buildings and other public health structures	• Reinforcing shorelines • Relocate buildings away from shorelines

7.4.1.1 Precipitation extremes and natural hazards

In response to the 1999 New Years' Day avalanche in Kangiqsualujuaq, Nunavik, the community, regional and provincial governments took action to minimize the risk of a future disaster of this nature (George, 1999). Several homes and community buildings were moved and reconstructed away from the danger zone at the base of the mountain, and the municipality extended the danger zone to 90 m on the basis of expert advice (Lied, 2000). Residents of the Labrador north coast (Nunatsiavut) stress the increasing importance of their search and rescue teams, in communities where they do exist, because of the possibility of such events in their mountainous locations (e.g. the northern-most community of Nain) (Table 7.13).

7.4.1.2 Unpredictability of weather conditions

Increasingly uncharacteristic weather patterns and events have had a significant impact on northern communities in terms of travel safety, and access to and participation in traditional land-based and subsistence activities. Northern residents have begun to cope or adapt in a variety of ways (Furgal et al., 2002; Lafortune et al., 2004; Huntington et al., 2005; Ford et al., 2006; Nickels et al., 2006; Tremblay et al., 2006) (Table 7.13). Changes in personal behaviours—and an increased reliance on some safety measures in view of the increased land and sea-based risks associated with uncharacteristic weather conditions—have been reported across the North. For example, communities in Nunavik report increasing their use and dependence on cabins out on the land while travelling, communicating weather conditions and observations among hunters more frequently while on the land by short-wave radio, and verifying conditions more vigilantly before setting out from the community (Communities of Nunavik et al., 2005). Residents of Arctic Bay, Nunavut report taking increased supplies on trips, identifying refuge areas from high winds during the summer boating season before setting out from the community, becoming more risk averse, and choosing not to go out on the water or land when conditions appear to be potentially shifting (Ford et al., 2006). As well, some residents report increased use of technologies such as GPS units to minimize chances of getting lost in bad weather conditions.

Residents across the North also recommend additional changes to further minimize risks associated with weather unpredictability. They include a return to the use of dog teams because of their greater dependability and innate navigation abilities in storms compared with snowmobiles and humans. They also include improvements in local analysis and dissemination of weather forecasting information from installations such as drilling camps and increased communications infrastructure (Communities of Nunavik et al., 2005; Communities of the ISR et al., 2005). However, it is important to note that many existing adaptation strategies or those recommended by northern residents, while increasing capacity to forecast conditions, may also create a false sense of security among hunters and other travellers by supporting an increase in travel that they would not otherwise undertake because of quickly changing or dangerous conditions. Currently, there are no data on the effectiveness of behavioural and technological adaptations in reducing the number of lost individuals, accidents or injuries in the North.

7.4.1.3 Temperature extremes

The majority of cold-related injuries are possible to prevent through appropriate protective actions although rapid unpredictable temperature changes present challenges. This is primarily because of a lack of experience (affecting attitude and skills), preparedness (e.g. vehicles, garments, supplies, logistics) and/or acclimatization (Hassi et al., 2005). A reduction in cold-related injuries is likely, however, assuming that the standard of cold protection, including individual behavioural factors or other adaptations, does not decline (Nayha, 2005).

Individual adaptive behaviours in the North are already being reported in response to heat extremes being experienced in some regions. Responses or adaptations such as ensuring access to cool areas in homes and altering physical activities outdoors (Furgal et al., 2002), installing screens in windows to increase ventilation in homes while protecting against the entry of flies and biting insects (Communities of the ISR et al., 2005), and/or increasing access to cooling areas (e.g. local swimming areas) have been reported. These have been reported mainly by older residents in response to respiratory stress and discomfort associated with heat extremes during the summer months (Communities of Labrador et al., 2005; Communities of the ISR et al., 2005) (Table 7.13).

7.4.1.4 Warming temperatures and changing ice conditions

Arctic coastal communities have reported changes in sea ice regimes and dynamics (Riedlinger and Berkes, 2001; Thorpe et al., 2002; Huntington et al., 2005; Ford et al., 2006; Nickels et al., 2006; Tremblay et al., 2006). Adaptations to these changes have taken a variety of forms; these have been primarily behavioural in nature (Table 7.13). For example, shifting the timing of hunting activities to compensate for reduced access to resources as a result of later sea ice consolidation and earlier breakup is commonly reported. In Arctic Bay, Nunavut, a portion of the overall narwhal quota for that community, an important traditional and economic species, has been shifted from the spring to the summer hunt in response to increasingly risky spring ice conditions; this shift increases both human safety and the chances of hunting success (Armitage, 2005; Community of Arctic Bay et al., 2005). Hunters in that community also reported taking supporting or alternate transportation (e.g. small boat) with them when travelling into uncertain ice areas (e.g. floe edge) where greater transportation flexibility is required.

In Nunavik, the regional government, communities and outside researchers have established a community-based ice-monitoring program in response to local concerns about ice safety and access to resources (Communities of Nunavik et al., 2005; Tremblay et al., 2006). Ice conditions are currently monitored, and information is communicated in three coastal communities in this region and one inland Naskapi community. This information is a collection of quantitative data on ice and weather conditions and qualitative descriptions on ice safety (Tremblay et al., 2006). Additionally, hunters in coastal communities of Nunavik report using new land-based or near-shore routes to access areas regularly reached by sea ice trails because of changes in ice stability (Lafortune et al., 2004). Some Nunavut communities now access satellite imagery of local sea ice conditions through the Internet before travelling to the ice edge, and use GPS to detect ice flow and movement to increase safety, and travel and hunting efficacy (Communities of Nunavut et al., 2005). Many communities are using similar adaptations for the same reasons in response to changes in lake- or river-ice conditions.

7.4.1.5 Increased exposure to UV radiation

Residents in a number of regions throughout the Canadian North have reported increased incidence of sun rashes and burns associated with a perceived increase in the intensity of the sun in recent decades (Furgal et al., 2002; Huntington et al., 2005; Nickels et al., 2006). In response, some individuals participating in community workshops on climate and environmental change have stated that they have begun to use protective creams more frequently. In some instances, they have stayed out of the sun (e.g. in a tent) while on the land in the summer when the sun's rays have felt particularly "hot" or increased their use of protective creams and clothing (Barron, 2006; Nickels et al., 2006).

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7.4.1.6 New and emerging diseases

Northern residents are taking some protective measures to minimize their possible exposure to new diseases moving northward with warming temperatures. In response to the observation of more and new biting insects in the region due to warmer summer temperatures, and concerns about the potential spread of disease, ISR residents in the western Arctic report an increased use of insect repellents and bug nets. More residents are installing screens to protect themselves against insect bites while increasing ventilation in their homes. In response to shifts in the number of animals found with visible abnormalities (e.g. worms in the liver of caribou), Aboriginal hunters have reported being more selective about the animals kept for human consumption. In Nunavik, current screening of trichinosis in walrus meat is done within 24 to 48 hours from the time of the kill, and communities are informed of the safety of the meat for raw consumption. Nearly all walrus-hunting communities in the region participate in the screening process and comply with the resulting public health advice.

Community leaders recommend public health education on potential new insect-transmitted and other zoonotic diseases that may emerge in the North with a warming climate. The purpose of this education is to alleviate concerns, and provide residents with information they can act upon to minimize their exposure to these emerging hazards (e.g. Communities of the ISR et al., 2005).

7.4.1.7 Threats to food security

The accessibility and availability of animals in many regions has changed, and not all individuals have been able to respond in a way that has ensured their regular access to traditional foods (e.g. elderly, those without the technological or financial means). Individuals have responded by changing the times of hunting activities to match changes in prey availability (both marine and terrestrial) (Ford et al., 2006; Guyot et al., 2006) (Table 7.13). Increased purchases of different marine and terrestrial transportation (e.g. faster or more powerful transportation vehicles, different kinds of vehicles) are also reported (Communities of the ISR et al., 2005; Ford et al., 2006). These purchases are being made to access hard-to-reach locations for fishing, hunting and gathering because of decreased water levels, increased storms or changes in route conditions (e.g. using an all-terrain vehicle

more often than a skidoo because of an increased snow-free season). As well, more flexibility appears to be required by some communities for hunting and gathering activities. In the community of Kugaaruk, Nunavut, residents typically rely on fishing when the ice is not safe for hunting. Fishing has now become more common, even at times of the year when, in the past, the ice conditions used to support travelling and hunting opportunities (Community of Kugaaruk et al., 2005).

The storage of wild foods has become increasingly difficult for hunters out on the land because of warmer summer temperatures and decreased amounts of permanent ice and snow. Consequently, hunters in Nunavut, the ISR and Nunavik report returning to the community with their catch more often during the summer hunting season to ensure that the meat does not go bad. This increases the need for personal or community freezer access to store wild meats (Ford et al., 2006; Nickels et al., 2006). In response to changes in accessibility of game, hunters in Nunavik communities have been able to cope. They report that they have not yet felt impacts that have changed the amount they harvest, rather simply how, where and how much they invest to access and harvest the same species (Lafortune et al., 2004).

However, some of the adaptations to date do not always provide benefits and may have indirect negative impacts. For example, there are increased costs associated with more powerful means of transportation (e.g. purchase of larger boats, use of more fuel) and hunters travelling farther and longer to access harder-to-reach species and animals (e.g. caribou) whose migration routes have changed. The implications for household budgets are not yet well understood.

7.4.1.8 Changes in drinking water quality and accessibility

Due to decreasing access to freshwater sources for drinking while on the land, northern Aboriginal residents in Labrador and the ISR report carrying bottled water with them more frequently when hunting and fishing (Nickels et al., 2006). The availability and accessibility of large pieces of multi-year ice for drinking water, which are preferred by Elders during winter months, is decreasing; consequently, some residents report using snow more often or travelling further to collect water (Nickels et al., 2006). Some communities report the need for more frequent testing of water from municipal systems and raw water sources to ensure safety and increase confidence in drinking water. Water system managers and public health professionals discussed the issue of water quality and environmental change at a workshop in Nunavik in 2005 (Martin et al., 2005b). Several responses to threats to water quality in the region were recommended:

- implementing small disinfection systems (ultraviolet (UV) radiation) at some locations in communities to avoid parasitic contamination;
- public education on household tank cleaning and evaluation of water quality (microbiological) before and after cleaning;
- public education on cleaning of plastic containers (used to store raw water in many households); and
- improving the surveillance of gastroenteritis.

Similarly, the Sierra Legal Defence Fund's (2006) Report Card on drinking water in Canada makes a series of recommendations to protect the safety of Canadians in the face of threats to drinking water, including climate change. For the territories in particular, they identified the need to adopt more stringent treatment standards. For Nunavut, they identified the need for protocols for public communication of water quality issues and the need to increase the frequency of testing (Sierra Legal Defence Fund, 2006).

7.4.1.9 Impacts on community and public health infrastructure

As a result of melting permafrost and increasing ground instability, communities have become concerned about damage to transportation and housing infrastructure. This is particularly important in communities where infrastructures are critical elements in the support of public health, such as drinking water sources, water treatment facilities, sewage containment areas, and transportation routes in remote and isolated communities.

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In some regions, communities are observing impacts of coastal erosion associated with increased storm surges and decreased sea ice cover, such as in the western Canadian Arctic. Adaptation to protect shorelines is taking place in the form of technological responses. In Tuktoyaktuk, NWT, the shoreline is reinforced with materials to decrease erosion and protect community buildings. An evaluation of the dynamics of coastal erosion around this community has been conducted, and potential plans for partial or complete relocation are being considered (Community of Tuktoyaktuk et al., 2005). Additionally, residents in this community and others in this region report having to move buildings in response to erosion and loss of shoreline (Communities of the ISR et al., 2005) (Table 7.13). Hoeve et al. (2006) conducted a scenario-based approach to assess the costs of adaptation to infrastructure (buildings) for the NWT. Although not exclusive to infrastructure critical to public health, it indicates the potential costs associated with erosion and permafrost melting. Costs in the NWT to address the impacts of melting permafrost on foundations ranged from $420 million ("worst-case" scenario, in which all foundations on permafrost required adaptation) to $200 to $250 million ("best guess" or conservative scenario, in which the thermal and physical sensitivity of each community was considered). Because human health and safety are threatened in northern communities from the combined forces of climate variability and change, a variety of adaptations are being developed. Their effectiveness and limits with regard to the rate and extent of climate change projected for northern regions are yet to be determined.

7.4.2 Adaptive Capacity

Adaptive capacities differ within and between regions and communities, as do exposures to climate variability and change throughout the North. A short review of the basic factors influencing adaptive capacity for health and climate change is provided in the text that follows.

7.4.2.1 Economic and material resources

The access to economic wealth among regions and communities facilitates the access to and implementation of various technological adaptive measures. For example, the access to resources to hire, equip and train search and rescue personnel at the municipal level can have significant positive impacts on reducing morbidity and mortality associated with strandings, and other events related to climatic extremes and weather-related natural disasters (e.g. storms, avalanches). The same can be said for other aspects of emergency management. The regional or municipal access to financial resources to fund, operate and maintain community freezers in communities can significantly aid in the adaptation of individuals to stresses related to country food security. According to community residents, these programs are no longer available in some communities and regions because of a lack of funds or the reallocation of funds to other priorities (Communities of the ISR et al., 2005).

Photo Credits: Peter Langer

The shifting ice seasons have significant impacts on ice-road networks in the western Arctic. These roads provide access to communities for the shipment of market foods and other products important to the health of northern residents. The construction of permanent all-weather roads is one potential strategy to adapt to the decreased stability of these roads. However, as Dore and Burton (2001) estimate, the costs associated with the construction of permanent roads in northern regions are very high (approximately $840,000/km, near Yellowknife). Based on a scenario in which 350 km of the territory's 1,400 km of winter/ice roads require replacement, projected replacement costs by the year 2100 for the NWT are in excess of $43 million (Dore and Burton, 2001).

Access to economic resources is as important at the individual level, as it is at the community level, to adapt to climate impacts on health. As reported by Ford et al. (2006) in Arctic Bay, the families of only some hunters were able to purchase critical equipment (e.g. larger boats) to adapt to changes in weather (e.g. increased storminess) and maintain a high level of hunting activity to minimize impacts to household food security. In this regard, household and individual wealth is critical in terms of adaptive capacity. Little attention has been given to examining the role of personal wealth in the ability to adapt at the household level, and to the associated variations in adaptation across regions of the North at this level. A review of basic socio-economic indicators shows that the economic capacity of individuals in Nunavut and Nunavik is significantly less than the average resident in other northern regions of the country (Table 7.6). This is in part associated with a limited number of economic options that renders these populations more vulnerable to changes in both local resource base (wildlife species) and global economic trends and markets.

7.4.2.2 Technology

Access to technology aids in the adaptation of individuals and communities to potential climate change impacts throughout the North. For example, the use of GPS units by younger hunters in some Nunavik and Nunavut communities has decreased the impacts of changing weather and ice conditions on the safety and ability to travel and hunt successfully in the Arctic environment (Communities of Nunavik et al., 2005; Communities of Nunavut et al., 2005; Ford et al., 2006). The use of larger boats by some hunters in Arctic Bay is an adaptation to the impacts of increased storminess, and allows them to continue hunting in these conditions. However, the adoption of such strategies also comes with a cost, in that individuals are increasing their exposure to these climate variables and therefore the net vulnerability is difficult to assess. This raises the issue of access to "appropriate technologies" and whether the knowledge base to use them effectively also exists in northern communities. The adoption of other kinds of technology, perhaps considered "basic" in other regions of the country, is often critically important in the North. For example, the installation of screens in the windows of homes in ISR communities helps alleviate the stress of extreme indoor temperatures on hot days while protecting residents from the increased presence of biting flies and other insects (Communities of the ISR et al., 2005). Across regions, the access to technology to adapt to currently identified health impacts associated with climate change appears to be limited by access to economic resources at household and individual levels.

7.4.2.3 Information and skills

Access to information and skills influences both individual and collective capacities to cope with and respond to the health impacts of climate change and variability. A review of basic education statistics in the North reveals fewer years of formal education on average in regions with a higher proportion Aboriginal population, such as Nunavut and Nunavik (Table 7.6). Access to skilled individuals who provide health services, such as general practitioners and specialists, and emergency health facilities is limited because of the remoteness of many northern communities. These issues are particularly evident in eastern Arctic regions where communities are not connected by roads; therefore, access to these services is further limited. As well, many northern regions face a high rate of turnover among local health centre personnel. However, it is important to note that, in small remote communities of the Canadian North, traditional knowledge and skills are just as important as the more formal information and skills for individual adaptation.

There is an increasing awareness of the value of Aboriginal knowledge and its role in adaptation to climate change and other forms of environmental change in the circumpolar North and around the world (ACIA, 2005). Aboriginal people have demonstrated considerable adaptive capacity and resilience in the face of change. Adaptive mechanisms such as "prey-switching" in response to changing animal abundance and distribution, and longer-term adaptation by using new tools and technologies such as GPS are two such examples (Berkes and Jolly, 2001). The value of local Aboriginal knowledge in this adaptation is demonstrated by the ability of northern hunters to safely navigate new travel and hunting routes in the face of decreasing sea and freshwater-ice stability and safety (Lafortune et al., 2004), and the ability of many Arctic Aboriginal groups to locate and hunt species that have shifted their migration times and routes, such as geese or caribou. The value of this knowledge is also in the foundation it provides for survival skills, and the ability to monitor ice safety and weather for travel in an environment with increasingly uncharacteristic weather conditions (Krupnik and Jolly, 2002; Nickels et al., 2002; Huntington et al., 2005; Guyot et al., 2006). However, there are limits to these adaptive abilities, and the thresholds at which adaptive capacity is insufficient to mitigate impacts must be identified.

The generation and application of traditional knowledge requires active engagement with the environment, close social networks in communities, and respect and recognition for the value of this way of knowing and understanding. Social, economic and cultural trends in some communities, and predominantly among the younger generation, indicate adoption of a more western lifestyle that is less intimately associated with the land. This has the potential to erode the cycle of generating and transferring traditional knowledge, and consequently the contribution of this knowledge to local adaptive capacity. Therefore, there are significant threats to the future of this element of adaptive capacity.

7.4.2.4 Institutional arrangements

Institutional flexibility enhances adaptive capacity by providing support for appropriate decisions to be made at the levels at which impacts are first recognized and response is required. The establishment of self-government regimes and natural resource co-management boards in the North allow for empowerment at local levels, and the orientation of decision making at the levels where the issues are first experienced and often best understood. For example, threats to traditional food security associated with increased climate variability require strategies to protect both resource numbers, and traditional and subsistence activities (Tesar, 2007). Recognizing the need for flexibility in hunting seasons for key food species that are adapting to shifts in regional ecology, and hunting new species moving into more northerly ranges are two such strategies (Chapin et al., 2004; Armitage, 2005; Huntington et al., 2005). Properly financed and supported, the devolution of power to flexible, local-scale decision-making bodies is more effective in making institutional arrangements in the face of climate variability and change.

The development of partnerships between northern communities and outside organizations provides the opportunity to enhance local adaptability and response, and in turn minimize health impacts. For example, the increased presence of companies in some sectors in the North may provide opportunities for communities to develop partnerships and enhance local search and rescue capabilities. Partnerships with Nunavik regional organizations, university researchers and the Public Health Agency of Canada are enhancing regional surveillance and monitoring capacity for food-borne and water-borne diseases that are likely to increase in the future with regional climate warming (Furgal et al., 2002; PHAC, 2006).

7.4.2.5 Community and public health infrastructure

Access to effective public health and emergency management services and infrastructure is a recognized determinant of health, and can support local-scale resilience in the face of projected health impacts of northern climate change. Although few studies on the status and distribution of basic public health infrastructure in the North have been conducted to date, there are some reports of local-scale challenges concerning drinking water surveillance and security (Sierra Legal Defence Fund, 2006). Northern regions are serviced with community health centres, regional hospitals and a medical evacuation system whereby residents are flown when required to better-equipped southern centres with specialists and emergency health care facilities. The number of medical doctors and specialists per capita is significantly less in the North. Greater staff turnover and less access to public health services are also a challenge for many northern residents, particularly Aboriginal people. Based on their geographic location, the smaller, more remote communities with no road network depend on air travel to link them to larger northern centres and southern cities. These communities are perhaps the most vulnerable to some impacts of climate change, such as those related to weather-associated natural disasters, because of their limited access to specialists and emergency health care facilities.

7.4.2.6 Disparities in health status

Northern populations in general have lower health status (Table 7.2). Indicators of health status discussed earlier suggest some health vulnerabilities among Aboriginal populations that can affect their ability to adapt. Lower life expectancy, higher infant mortality, a higher percentage of low-weight births (e.g. Nunavut and Nunavik), and a significantly higher number of accidents compared with the national average characterize the population today. Among the general northern population, health services and health status are improving. However, as noted by the Government of the Northwest Territories (GNWT, 2005) and others (Statistics Canada, 2005), the status of northern Aboriginal populations continues to be poorer for some indicators (e.g. lower life expectancy in all regions, higher rates of accidents in communities in the NWT).

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In fact, Aboriginal health status in the country has remained the same or worsened over the past 10 years (Young, 2003). The disparities in health status, and in particular the significantly lower status among Aboriginal groups in the North, influences the levels of adaptive capacity and vulnerability to climate change impacts on health throughout the Arctic. The generally lower health status among the Aboriginal population, in particular, limits their adaptive capacity and ability to minimize the health impacts of climate change.

7.4.2.7 Socio-ecological resilience

There is a growing body of literature on the historical adaptive abilities of Aboriginal groups in the circumpolar North and the applicability of these strategies today for addressing impacts from climate change. The adaptive capacity among Aboriginal groups that lived in the North in the past was associated with a combination of strong human and social capital, social and cultural organizational flexibility, the ability to understand and respect human relationships to the land, and to generate, share and apply locally developed land-based knowledge. This socio-ecological resilience (which is a function of adaptive capacity) was critical for the survival of Aboriginal peoples throughout the North over thousands of years (Chapin et al., 2004). Historically, cultural adaptations and the ability of Arctic Aboriginal people to use their local resources have been associated with, or affected by, seasonal variations and changing ecological and climatic conditions. One of the hallmarks of successful adaptation in Arctic resource use has been flexibility in the application of technologies and social organization, and the knowledge and ability to cope with change and circumvent some of its negative impacts. Some of these characteristics still exist in many communities today whereas in other communities they have been eroded by social, cultural and economic shifts over recent decades. For example, Chapin et al. (2004) report how Aboriginal groups in the European Arctic have developed resilience by sharing resources, even in the cash sector of the economy, through kinship networks that link hunters with office workers.

In the past, responses to major climatic and environmental changes included changing group size or moving to new locations, being flexible with regard to seasonal cycles and harvesting, and establishing sharing mechanisms and networks for support (Freeman, 1996). Many of these strategies, with the exception of moving communities, are still employed in various ways in the Canadian North (Berkes and Jolly, 2001; Nickels et al., 2002; McCarthy et al., 2005; Ford et al., 2006) (Table 7.13). However, they will likely be constrained in the future by continued shifts toward a more sedentary, "western" lifestyle and livelihoods that challenge the connection between people and their local environments.

7.4.2.8 Disparities in adaptive capacity

Disparities in adaptive capacity exist between Aboriginal and non-Aboriginal people, and between remote and larger regional centres in the North (Tables 7.3–7.7). The pattern of disparities in terms of adaptive capacity differs from location to location, based on a variety of factors. Residents in larger regional centres closer to north-south transportation connections (e.g. road networks, regional airports) are more heavily engaged in wage-based employment and are less dependent on local resources for household sustenance. Their livelihoods are at lower risk from climate conditions, and they have a greater ability to respond to weather extremes and other hazards. They often have greater access to economic resources to purchase needed transportation and hunting equipment, market foods when land-based foods are scarce, and they have easier access to emergency medical services in the event of accidents. More frequently, these are communities with proportionately larger non-Aboriginal populations.

In terms of social capital, traditional skills and knowledge, and access to a diversity of environmental resources, the more remote, smaller communities are better equipped to adapt to changes and variability in local environmental conditions. For example, many residents in these communities have the traditional knowledge to find new hunting locations and routes, the traditional survival skills to travel in dangerous weather, and extended social networks to spread the risk of impacts among a larger number of individuals. However, a number of social and economic inequities disadvantage Aboriginal populations in terms of their ability to adapt. The analysis of capacity at the community level is solely based on the qualitative review of data presented here, and warrants further investigation. A more detailed local-scale understanding of climate impacts and the factors that influence adaptation requires further attention in order to best support the development of skills and abilities that facilitate local response and minimize negative impacts.

7.5 KEY VULNERABILITIES

The assessment of vulnerability to the impacts of climate change on health in an area as large and diverse as the Canadian North is a challenging exercise. Based on the information presented in this chapter, some general observations can be made about key vulnerabilities to climate change health impacts that exist in Canada's North. Key vulnerabilities exist where individuals or groups are already highly exposed and where exposure is increasing or likely to increase, and where there is limited or challenged adaptive capacity to respond to these impacts. In general, many of the vulnerabilities to health risks from climate change in the Canadian Arctic are the product of a combination of environmental, socio-economic, lifestyle and political changes. Vulnerabilities are summarized by key climate and health impacts in the text that follows.

7.5.1 Precipitation and Natural Hazards

Communities located in mountainous regions (e.g. some subregions of the Yukon, and eastern communities of Baffin Island, Nunavik and Labrador), which are less accessible by road networks and located within avalanche-prone areas, are particularly vulnerable to continued winter warming and increases in precipitation which can trigger avalanches and landslides. According to Bradley (2005), communities with established emergency plans and access to emergency transportation are less vulnerable to the impacts of such environmental disasters in Arctic regions. Re-zoning studies, identification of hazard areas and relocation of buildings away from these areas, as has been done in Nunavik (Lied, 2000), can significantly reduce future exposure and therefore vulnerability. Similar measures in other at-risk regions will have similar positive benefits in reducing exposure, increasing adaptive capacity and, as a result, reducing vulnerability.

7.5.2 Unpredictable Weather, Ice Conditions and Travel Hazards

Aboriginal populations, who spend significant amounts of time on the land and sea away from communities, and who have a strong reliance on their local environments for traditions, culture and subsistence, are the most highly exposed groups in the North to changing and uncharacteristic weather conditions. Current exposure to these hazards is high, particularly in smaller, more remote communities where traditional activities are still a regular part of everyday life. With projected changes and fluctuations in the climate system, exposure is expected to remain high. Many coastal communities also report a shift in ice seasons and an increase in ice instability, and associated travel dangers. As noted previously, land-based accidents are more common in small, remote communities and occur predominantly among young male Aboriginal residents (GNWT, 2004). However, according to Elders, traditional cues for predicting environmental variability no longer work because of the increasing unpredictability of northern climatic conditions and weather. (Chapin et al., 2005; Huntington et al., 2005; Nickels et al., 2006). This strips residents of their knowledge, predictive ability and self-confidence in making a living from their resources, and may ultimately leave them as "strangers in their own land" (Berkes and Jolly, 2001). Social, economic and cultural trends in the North suggest an increasingly sedentary population that is more engaged in wage-earning employment. With these trends, the current wealth of adaptive capacity that comes from regular, frequent and extended, close interactions with the environment is being eroded. Consequently, the vulnerability of Aboriginal people, and especially youth and young hunters, to these hazards will increase in the future.

7.5.3 Temperature-Related Injuries

Projected winter warming and future improvements in access to preventative medical services throughout the North can be expected to decrease vulnerability to cold-related injuries and mortality. However, increased extreme temperatures in the summer are already reported to be creating heat stress among some sensitive groups, such as the elderly and those with pre-existing respiratory conditions, as was reported by Inuit Elders in Nunatsiavut and the Inuvialuit regions. Current adaptations to extreme warm temperatures seem adequate to date; however, some challenges are faced by those who are less mobile and have limited access to cool buildings and appropriate ventilation (Communities of the ISR et al., 2005). As hot summer temperatures continue to increase in number and severity, and the number of elderly residents grows (Tables 7.1 and 7.2), there is a need to monitor the vulnerability of this at-risk group throughout the North.

7.5.4 New and Emerging Diseases

Current levels of exposure to many zoonotic and vector-borne diseases in the North are generally not well monitored. Evidence from Nunavik shows the current exposure to some diseases that have had an impact on health in that region in recent decades (Table 7.11). Residents in the western Arctic have reported increasing numbers and species of insects in recent years, indicating a potentially higher level of exposure to some potential vectors (Communities of the ISR et al., 2005). Residents of all regions, who regularly consume traditional food, will face increased risk of infection by some zoonotic diseases that are projected to increase in the North in the future, particularly if the wildlife they eat is raw or fermented as per traditional techniques. The greatest vulnerabilities are among Aboriginal residents residing in small remote communities where these practices are more common. These residents are also the furthest from emergency medical services and appropriate treatment in the event of infection. As indicated by residents in the western Arctic, public education on the health risks related to new and emerging diseases is needed, and would likely strengthen adaptive capacity and reduce vulnerability (Community of Tuktoyaktuk et al., 2005). Screening for *Trichinella* in Nunavik is one example of a measure to reduce vulnerability in that region (Proulx et al., 2000).

7.5.5 Traditional Livelihoods, Food and Water Security

Livelihoods and aspects of health that are dependent on the hunting, fishing and gathering of land- and sea-based resources are already being impacted by changes in environmental conditions associated with climate change in many regions. According to Duhaime et al. (2002), households that are led by a single female have the least access to traditional foods in Nunavik. According to Nickels et al. (2006), existing community traditional food-sharing programs are already under stress, and there is a need for the development

of new programs in some communities. Households that are dependent upon and have access to only a few species in their local environment, and that have limited access to healthy alternatives, are the most vulnerable to the impacts of climate change on food security (e.g. female-led single-parent households in small communities of Nunavik and Nunavut) (Tables 7.6 and 7.7). In many instances, these individuals and households are already reporting significant stress on household food security. This is likely to increase with projected climate change in these regions.

Communities are most vulnerable to the impacts of climate warming and water-borne infections where significant amounts of raw and untreated water are used for drinking, especially by children and youth. This is particularly the case where access to treated water is limited, where warming is experienced, and where there is little surveillance and monitoring capacity. Currently, it is difficult to identify specific communities and regions where these conditions are present because of the lack of comparable local-scale data.

7.5.6 Permafrost, Coastal Erosion and Community Infrastructure

Exposure to the health impacts of permafrost melting and the destabilization of community infrastructure is highest in the western Arctic where considerable warming has been experienced in recent decades. It is significantly pronounced in low-lying coastal communities because of the combined effects of permafrost melting and coastal erosion (e.g. Tuktoyaktuk, NWT). Current capacity to adapt to these changes, which are projected to continue throughout the North where communities are settled on permafrost, is limited because of the need for significant capital investment to repair and replace damaged or threatened infrastructure.

In general, exposure is much higher, and projected to increase, among individuals living in small, remote, northern coastal communities with proportionately higher Aboriginal populations. A disproportionate burden of risk is being placed on this specific segment of the population which is already considered to be "at risk" or vulnerable to a number of health effects. Accordingly, the social and environmental justice dimensions of climate change need to be recognized for this population in Canada (Lambert et al., 2003).

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7.6 KNOWLEDGE GAPS AND CONCLUSIONS

Research on climate change and health among Canadian Arctic populations is still developing (Berner et al., 2005; Climate Impacts and Adaptation Research Network, North Region (C-CIARN North), 2005; Furgal and Séguin, 2006). Knowledge of impacts and adaptations, and the capacity of Northerners to respond, is growing. To date, most of the research on climate change in this region has focussed on the nature of biophysical changes taking place rather than on the impacts of those changes to human health vulnerabilities. Comparable local-scale information is required to provide a clearer indication of the relationships between climate change and the health of Northerners, and to support the development of appropriate and acceptable response strategies in the future (Ford et al., 2006; Nickels et al., 2006). This assessment of vulnerabilities revealed some important challenges and gaps in the knowledge base. These range from basic data needs to the lack of local and regional studies and an understanding of key climate–health relationships in light of projected changes at local and regional scales. A summary of key knowledge gaps and recommendations are presented in the text that follows.

7.6.1 Knowledge Gaps and Research Recommendations

One of the most important limitations to the study of climate change effects on human health in Canada's North is the lack of comparable health statistics for key health outcomes which are potentially influenced by climate and environmental change for many regions. The paucity of comparable data and its collection over time, at regional and local scales, presents a significant challenge to the ability to assess the vulnerability to climate change. Because vulnerability to climate change is influenced by a number of socio-economic, geographic, health status and institutional factors, the collection of comparable information on these variables is also required. The analysis presented in this chapter identifies key information gaps in the following areas:

- water quality and community water infrastructure;
- level of emergency preparedness at the community level;
- incidence of climate-sensitive zoonotic diseases and vectors;
- cause-related injuries data;
- status of traditional food security and the factors that affect it in some regions;
- status of agricultural practices and possibilities for development in the future;
- status of key elements influencing adaptive capacity and their distribution at the household, community, territorial and regional scales (e.g. income, seasonal income, access to employment); and
- data sets across the North for key climate and health indicators.

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Much of the knowledge of current health vulnerabilities in northern populations is based on very few focussed studies within the health sector. The research approaches used to collect the information required to better understand these issues (e.g. local workshops, interviews with local residents) can also yield benefits such as the immediate enhancement of local capacities by increasing local knowledge of impacts and stimulating discussions of needed solutions. As reported by Furgal and Séguin (2006), adaptive strategies developed at the local scale appear to be most appropriate and sustainable over the long term. Therefore, the processes used to better understand climate change and health vulnerability in northern regions must engage local communities and individuals. To address the key knowledge gaps and enhance local capacities to adapt, the following research activities are recommended to be undertaken in cooperation with local and regional bodies throughout the North:

- regional risk assessments to adequately assess the relative importance of certain climate exposures on human populations;
- the changing epidemiology of environmentally influenced morbidity and mortality in northern populations (e.g. understanding patterns of injuries and diseases and the role that many of the factors that influence adaptive capacity play in these diseases);
- the impact of climate change and environmental variability on northern food security;
- impact and adaptation studies among the northern non-Aboriginal population;
- local-scale health vulnerability studies including the relative importance of key socio-economic factors in the adoption of adaptations or health protection measures;
- documentation and assessment of individual and collective health adaptations to climate and environmental change;
- improvement of regional-scale climate scenarios and models for use in health impact assessment; and
- integrated human, biophysical and natural system climate studies at the local and regional scales.

Future research will also benefit from the enhancement of local analytical capacity to assess and use climate- and health-related data for policy and program decision making and the development of regional monitoring and surveillance capacity to establish a northern-wide comparable baseline with regards to climate-influenced northern health impacts.

7.6.2 Conclusions

There are a number of important stressors acting on northern societies today. Climate change will likely accelerate the effects of some, exacerbate others, and alleviate a few. The demographic pressures of a young and growing population, as well as unprecedented social, cultural and economic trends will continue to challenge the capacity of these regions to adapt to climate change. According to Last and Chiotti (2001), public health education and promotion programs related to several climate and health topics, the development of new technologies, and epidemiological surveillance and monitoring have the ability to minimize the vulnerability of northern residents and communities.

While many Aboriginal residents may be more highly exposed than others to climate-related hazards, they can draw on strong traditional skills and cultural assets to mobilize capacity to adapt to change. Strategies to mainstream or formalize the development of adaptive capacity, in association with other forms of public health education on these topics, may prove valuable in enhancing adaptive capacity and reducing vulnerability in the future (e.g. traditional knowledge and skills camps on the land; economic support programs for hunting, fishing and gathering).

There are known gaps in the health monitoring and surveillance capacity; the development of priority indicators of the health impacts of climate change for the North could inform necessary efforts to enhance this capacity. Recent advances in this area include those of Health Canada and the Public Health Agency of Canada in the area of food- and water-borne disease research activities, surveillance and monitoring in northern communities related to climate change, and in supporting the sustainability of health in communities through the Aboriginal Head Start program. As well, Gosselin et al. (2006a, 2006b) are currently conducting a comprehensive review of surveillance capacity in Inuit land claim regions in the context of changing regional climates and potential impacts to health. Current community-based participation in research activities is also taking place under the International Polar Year, and initiatives are underway under the ArcticNet (Network Centres of Excellence) and other programs (e.g. Northern Contaminants Program). They are making important contributions to the collection of baseline information upon which monitoring can continue, and are helping to understand the problems and how best to address them. With this information, much more will be learned about the existing response capacity across the North and where best to focus efforts to strengthen abilities and address current and future vulnerabilities.

The assessment of vulnerabilities presented in this chapter represents an early step in the development of an adequate understanding of complex and interrelated issues in the Canadian North. Significant efforts are required to increase the knowledge of these issues and the capacity of northern populations to respond as the North continues to change. Individuals, communities and governments need to work together to take proactive steps to develop and enhance capacity. Recognizing that the public health system in northern Canada is still relatively underdeveloped, improved access to basic health services will contribute to reducing the health impacts of climate change. However, the health sector cannot alone address all the risks faced by Northerners; collective actions across a number of sectors are necessary to strengthen community adaptive capacity and provide individuals and communities with the needed solutions.

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