Chapter 1

Introduction

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1.1 CLIMATE CHANGE AND THIS ASSESSMENT

1.1.1 Introduction

For more than two decades, findings of the scientific community have indicated that the Earth's climate is rapidly changing. The Intergovernmental Panel on Climate Change (IPCC) states that "warming of the climate system is unequivocal," and its conclusion is supported by observations of increases in global air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level (IPCC, 2007c, p. 5). Natural processes have always influenced global climate, but human activities, in particular the burning of fossil fuels and changes in land use patterns, are considered to be the main reasons for the climatic changes observed since the mid-20th century (IPCC, 2007c). In Canada, average national temperatures have increased 1.2°C over the past 50 years and an even greater rate of warming is projected over this century (Government of Canada, 2006).

Climate change is a global phenomenon that leaves no part of the world untouched. Everywhere, changes in climate are having observable impacts on both natural and human systems—water resources, ecosystems, food and forest products, coastal systems and low-lying areas, industry, settlements and societies, and human health, involving significant social, economic and environmental consequences (Stern, 2006; IPCC, 2007c). As these changes occur, adaptations to protect Canadians and their communities need to be developed and implemented. Adapting to climate change requires that decision makers and individual Canadians adjust their activities and plan for events and conditions that, in some instances, have not yet been fully experienced. Scenarios of future global or regional climate can act as guides for planning a safe and prosperous future for future generations around the world.

Periodic assessments of vulnerabilities to climate change are necessary to inform and support the processes of adaptation. Knowledge about the health impacts of climate change is growing rapidly and is increasingly being shared around the world. Several recent publications examining the effects of climate change at the global, national and regional levels have highlighted the health impacts of climate change on populations (McMichael et al., 2003; Berner et al., 2005; Menne and Ebi, 2006; Stern, 2006; Confalonieri et al., 2007).[1] It is widely recognized that efforts must focus on assessing current and future health vulnerabilities in order to identify actions to help those affected, especially the most vulnerable.

This Assessment provides the most up-to-date synthesis of knowledge on how the health of Canadians is affected by the climate and what lies ahead under future climate scenarios. It explores how governments, communities and individuals are drawing on current capacity to address and mitigate the effects of climate on health. These analyses identify vulnerabilities to health and areas where added vigilance and new knowledge are required to protect the health of Canadians.

1 A list of national impact assessments of climate change can be found in the Health Chapter of the IPCC Fourth Assessment Report (Confalonieri et al., 2007). The World Health Organization has also completed, or participated in, a number of assessments of climate change health risks (McMichael et al., 2003; Menne and Ebi, 2006).

1.1.2 Origins of the Assessment

In the past decade, Canada has initiated and participated in several assessments of the impacts of climate change, which have included some of the possible effects of climate change on health. The first report, the *Canada Country Study: Climate Impacts and Adaptation,* included a review of published literature on the effects of climate change on health in Canada (Koshida and Avis, 1998). In 2008, a second comprehensive assessment, *From Impacts to Adaptation: Canada in a Changing Climate 2007,* was released; it reports on key issues facing each region of the country, including health (Lemmen et al., 2008). The *Arctic Climate Impact Assessment* was a notable international initiative that profiled the health effects of climate change on Arctic populations, including those in Canada (Berner et al., 2005).

In planning this Assessment, Health Canada recognized the need to understand the significance of future climate scenarios and of global and local environmental change for the health of the population. The Assessment provides decision makers with an integrated perspective regarding the vulnerabilities of Canadians. It was also considered necessary to set a course for future research, policies and actions. Consequently, in 2003, Health Canada initiated a consultative and investigative assessment process, informed by the approach proposed by the World Health Organization (WHO) in its 2003 publication *Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change* (Kovats et al., 2003).

The process for this Assessment was guided by a National Steering Committee, with representation from various public and private organizations, and with input and advice from over 350 stakeholders, practitioners, government decision makers and researchers in a series of activities (e.g. scoping workshops, table-top simulation exercises, committee meetings, key interviews, peer reviews). The diversity of views broadened the scope of inquiry, challenged assumptions and strengthened the analysis. This Assessment is the first of its kind in Canada to focus on health vulnerabilities, conducted by health and environment researchers and supported by experts from many other disciplines and fields.

1.1.3 Scope and Organization of the Report

The National Steering Committee recognized the limitations of current knowledge, research capacity, and data availability and completeness. Therefore, the approach and scope of this initiative was intended to meet the following objectives:

- develop a baseline of evidence concerning the relationship between a changing climate and direct and indirect impacts on health;
- establish a framework for analyzing adaptive capacity and define the ability of selected populations to cope and adapt to specific impacts;
- demonstrate the usefulness and replicability of the methods employed in this Assessment; and
- establish partnerships to advance policy and scientific work in this area.

This Assessment brings together information collected through a wide range of methods (literature reviews, modelling studies, table-top simulation exercises, key informant interviews and population surveys) to present evidence of risks to health from climate change, along with vulnerabilities of concern. It comprises investigations on both national and regional scales. Much of the data were collected at the sub-national level; consequently, useful lessons can be drawn from this exercise for future application at the local, regional and provincial levels in Canada, and to provide relevant advice for policy decisions at all levels of government.

Chapter 1

The Assessment is organized as follows:

The present chapter summarizes the scope and organization of the Assessment. It then presents background information on climate change in Canada helpful to understanding the relationship between climate change and health. The assessment process and the content of the chapters then follow.

Chapter 2, Assessment Methods, discusses methodologies used for this Assessment, as well as their general limitations, including the topic of uncertainty. It should be noted that some chapters use methods and practices appropriate to their specific investigations, and these are discussed in detail in the respective chapters.

Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, examines the occurrence of climate-related natural hazards in Canada. It reviews the impacts of such events on health, and the systems and measures in place to mitigate these impacts. It also proposes research directions, policies and measures that are needed to reduce future risks.

Chapter 4, Air Quality, Climate Change and Health, provides a brief overview of the impact of air pollution and the effects of its interactions with warmer temperatures on health. It examines the effects of one future climate scenario on air quality in Canada, and uses modelling to predict future impacts on health. It also discusses current Canadian risk-management strategies, including key research needs on this subject.

Chapter 5, Impacts of Climate Change on Water-, Food-, Vector- and Rodent-Borne Diseases, reviews the potential effects of climate change on the risks in Canada related to specific diseases that originate from food and water sources, and from insects, ticks and rodents. It summarizes current key public health activities that protect populations, and discusses future directions for research and risk management.

Chapter 6, Health Impacts of Climate Change in Quebec, and Chapter 7, Health Impacts of Climate Change in Canada's North, are assessments of vulnerabilities to health in two regions of the country; both cover the full scope of the issues addressed in this Assessment. These regions were selected because of the availability of data, case studies, and research expertise.

Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada, assesses adaptive capacity by examining the current capacity to handle increasing exposure or sensitivity of the population to certain climate risks and to manage climate-sensitive diseases. It also reviews measures that have been developed to strengthen the ability to manage these risks, and provides insights on how future population exposure and sensitivities might change in Canada.

Chapter 9, Conclusion, reflects on the findings of all chapters and presents five themes common to all. Under each theme, it highlights findings that have the potential to influence current policy and program decisions as well as future research directions in Canada.

1.2 CLIMATE CHANGE AND CHANGING WEATHER

1.2.1 Weather, Climate Variability and Global Climate Change

In studying the effects of climate change on health, it is important to distinguish the effects of several meteorological exposures: weather, climate variability and long-term climate change (McMichael et al., 2003). Climate is the average day-to-day weather defined by variables such as temperature, precipitation, humidity, cloud cover and wind. Climate variability is a departure from the average climate, including seasonal variations and large-scale regional cycles such as El Niño. Occurring over decades or even longer time-scales, climate change is a sustained shift from the usual or expected climate patterns for a particular area (Environment Canada, 2001). On a global scale, climate change means a long-term shift in the Earth's prevailing weather that can be measured by key weather variables (e.g. temperature, precipitation).

Over the past century, the world has become warmer. The total temperature increase has been approximately 0.76°C (from 1850–99 to 2001–05). Eleven of the last 12 years (1995–2006) rank among the warmest years on record (IPCC, 2007c). Numerous other changes in climate have also been observed. These include changes in Arctic temperatures and ice, precipitation patterns, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones (Confalonieri et al., 2007). Reductions in greenhouse gas (GHG) emissions are considered necessary to limiting the rate and magnitude of future climate change. However, owing to the inertia of the Earth's climate system, further warming and the associated changes in climate parameters, such as precipitation patterns and extreme weather events, are expected to continue (Confalonieri et al., 2007).

Major advancements in the number of simulations that are available from a broad range of models, which cover a range of possible futures, provide a quantitative basis for estimating the likelihood of many aspects of climate change (IPCC, 2007c). Global atmospheric models project that, over the next two decades, global temperature will increase by 0.2°C per decade. Even if atmospheric concentrations of GHGs were kept constant at year 2000 levels, global mean temperature would still increase by 0.1°C per decade. Geographic variation in the amount of warming is projected, with the greatest warming occurring over land and at high latitudes (IPCC, 2007c). Precipitation is also projected to increase more at high latitudes, whereas decreases in precipitation are expected in most subtropical land regions (IPCC, 2007c). Warmer temperatures will be accompanied by continued contractions in snow cover, reduced extent and duration of Arctic sea ice, and an increased permafrost thaw depth. These patterns represent a continuation of observed trends (IPCC, 2007c).

1.2.2 A Changing Canadian Climate

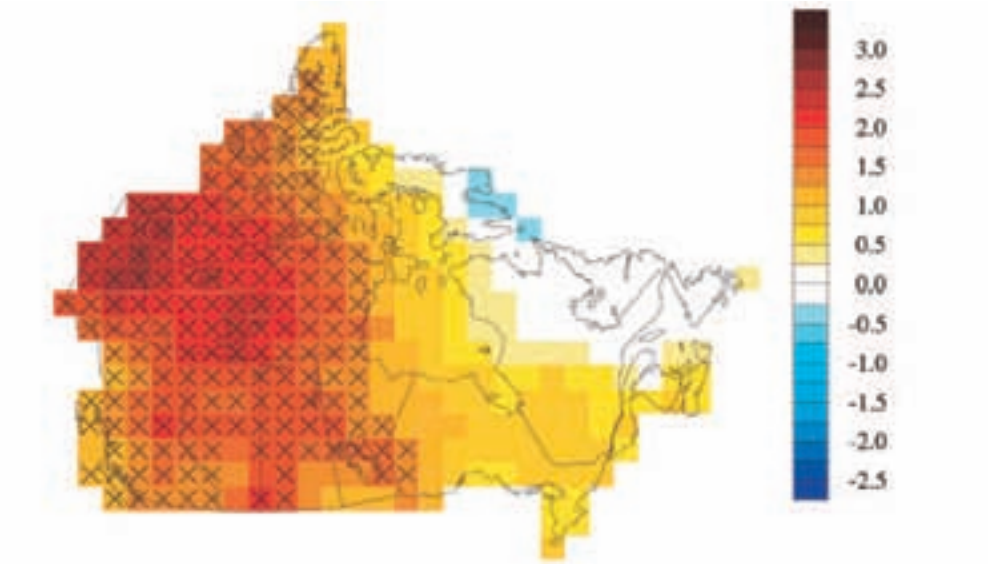
The geography of Canada is vast and diverse, covering 48 degrees of latitude from Pelee Island in the south to the Arctic Ocean and extending across from the Atlantic to the Pacific oceans. This land mass has a varied topography and considerably different ecosystems and climate regimes. The Canadian climate is characterized by great variability on both seasonal and inter-annual scales.

An examination of historical records indicates that Canada's average temperature has increased 1.2°C over the past 50 years. Historical records can provide some indication of the direction of changes, but the complexity of the Earth's climate system is such that predicting what changes are likely to occur in the future requires more sophisticated analyses. Mathematical models and scenarios integrating various climate influences and detailing the implications of changes for North America and Canada are available and continue to be

improved. In recent years, Canada has supported several initiatives to develop regional projections that take into account socio-economic factors and other regionally relevant environmental variables. The Canadian Foundation for Climate and Atmospheric Sciences, the Meteorological Service of Canada, the Canadian Climate Scenarios facility at the University of Victoria, Ouranos and climate modellers at other Canadian universities are contributing to the development and refinement of regional climate projections for Canada. These models are considered to provide plausible projections of potential changes for the 21st century.

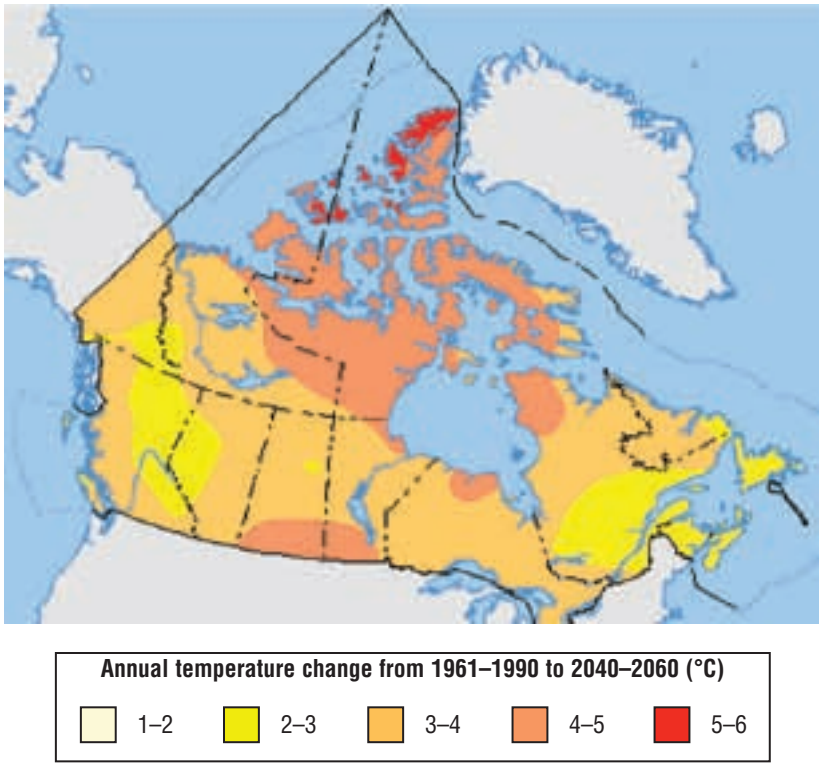
It is projected that Canada will continue to experience greater rates of warming in this century than most other regions in the world (Government of Canada, 2006). The Yukon and the Northwest Territories are experiencing the greatest warming, whereas there has actually been some moderate cooling over Baffin Island in the eastern Arctic (Figure 1.1). Projected increases in temperature vary, with the Arctic and the south-central Prairies warming the most (Figure 1.2). Precipitation has increased over most of the country, with the exception of the Prairie provinces and the eastern edge of Baffin Island (Figure 1.3). However, general statistics do not show that while precipitation has increased, it has also become more irregular. This trend will continue in the future; some areas will experience more intense rainfall, possibly causing floods, and others will experience record-setting periods of drought. In general, annual precipitation is projected to rise in many areas, accompanied by more frequent heavy precipitation events, less precipitation during the growing season and more precipitation during the winter (Lemmen et al., 2008) (Figure 1.4). Of interest to climate and health researchers are the projected changes in both these climate variables (i.e. temperature and precipitation) and the regional variation in their distribution; these point to the importance of regional- and local-scale studies in determining risks and vulnerabilities.

Figure 1.1 Regional distribution of linear temperature trends (°C) observed across Canada between 1948 and 2003



Note: The symbol X indicates areas where the trends are statistically significant.
Source: Zhang et al., 2000 (updated 2005).

Figure 1.2 National annual temperature scenario 2050: A simulation of projected changes in annual mean temperatures for Canada for the period 1961–90 to 2040–60

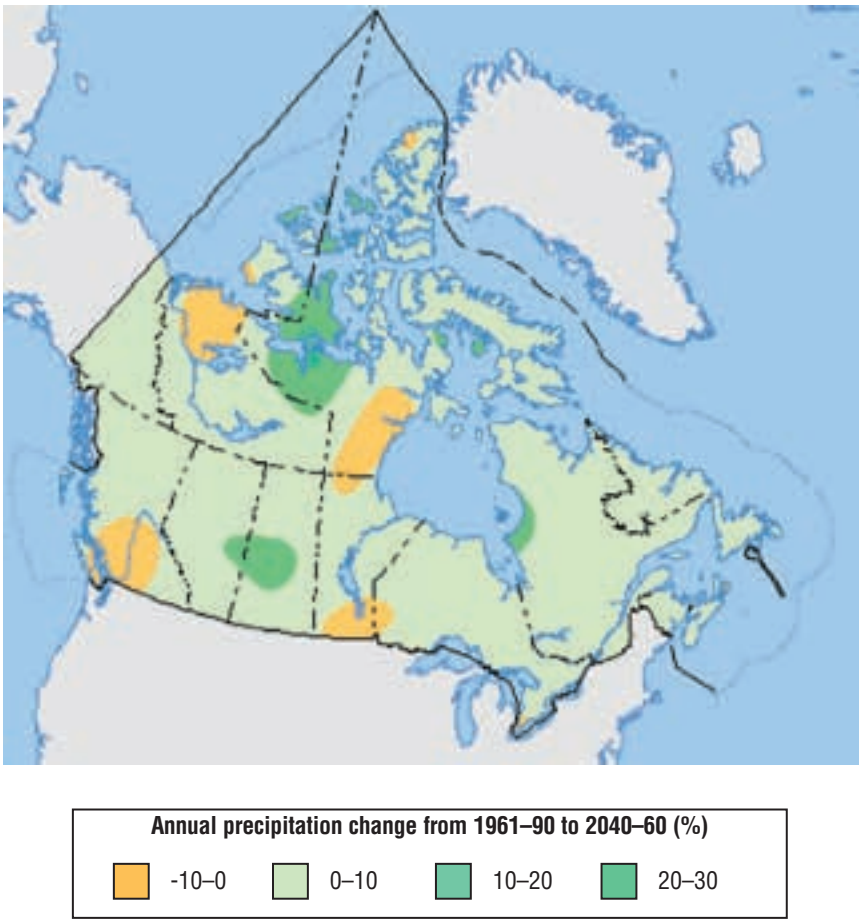


Source: Atlas of Canada, 2003b.

Figure 1.3 Regional distribution of linear precipitation trends (%) observed across Canada between 1948 and 2003

Note: The symbol X indicates areas where the trends are statistically significant.
Source: Zhang et al., 2000 (updated 2005).

Figure 1.4 National annual precipitation scenario 2050: A simulation of projected changes in annual mean temperatures for Canada for the period 1961–90 to 2040–60



Source: Atlas of Canada, 2003a.

1.2.3 Impacts of Climate Change in Canada

In its *Fourth Assessment Report,* the IPCC noted a marked increase in studies of observed trends in the environment and their relationship to regional climate change since its *Third Assessment Report* in 2001. The panel concluded, "There is high confidence that recent regional changes in temperature have had discernible impacts on many physical and biological systems" (IPCC, 2007b, p. 2). Natural systems that are being affected by regional climate change, particularly changes in temperature, include changes in snow, ice and frozen ground; shifts in the ranges and species of plants and animals in terrestrial, freshwater and marine systems; earlier timing of spring events; and changes in ocean salinity, pH, oxygen levels and circulation (IPCC, 2007b).

All regions of Canada are experiencing climatic change, but the experience can vary widely across the country. The impacts of climate change are especially visible and immediate in Canada's northern regions. The effects of the gradual warming of temperature on ecosystems and economic activities dependent on natural resources (e.g. agriculture, forestry, fisheries, hunting) are also being observed. Shifts in average climate conditions

are expected to be accompanied by changes in climate variability, increasing the frequency of some extreme weather events. Across the country, injuries, evacuations and economic losses from weather-related disasters in Canada are reported to be on the rise in the past decade and can be in the hundreds of millions of dollars (PSEPC, 2005; Lemmen et al., 2008). Recent events such as the 1998 Ice Storm in eastern Canada, Hurricane Juan in 2003 in the Maritimes, and the Peterborough and Toronto floods in 2004 and 2005, respectively, have shown that climate variability can overwhelm infrastructure and communities in this country, and cause irreversible changes to ecosystems. Canadians have also begun to experience the kind of heat waves that scientists predict will become much more common. For example, by 2050, hot summer days in southern Canada exceeding 30°C are estimated to be four times more frequent than today (Environment Canada, 2005). Coastal areas will continue to be at risk from erosion, extreme weather events and sea-level rise (Riedel, 2004). The most up-to-date assessment of climate impacts in Canada, *From Impacts to Adaptation: Canada in a Changing Climate 2007,* assesses the body of knowledge regarding Canada's vulnerability to climate change, as well as potential future benefits (Lemmen et al., 2008). In each regional chapter, current and anticipated climate impacts are reported, with a focus on human and managed systems, including human health.

1.2.4 Vulnerability to the Impacts of Climate Change

Humans are directly exposed to climate change through changes in weather patterns, such as more intense and frequent extreme weather events and changes in average seasonal temperatures and other climate variables like precipitation and winds. But the influences of climate go well beyond experience of the weather; they play key roles in most life-supporting systems. The breadth of the influences of climate change on biological and physical systems and the unpredictable nature of extreme weather events can increase vulnerability to climate change impacts. However, understanding vulnerabilities within society is a complex process that must go beyond knowledge of the environmental effects of climate change. It requires knowledge of the interactions between three variables:

- exposure of individuals or populations to the impacts of climate;
- sensitivity to the impacts; and
- adaptive capacity of individuals, populations and institutions (also known as ability to cope with consequences or the ability of a system to manage change).

Many frameworks have highlighted the links between these three variables, but little guidance has been offered on how to integrate their analyses. Together, analyses of exposure, sensitivity and adaptive capacity provide insights about vulnerability. In the field of climate change impacts and adaptation, vulnerability refers to "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007a, p. 883).

1.3 CLIMATE CHANGE AND HEALTH

1.3.1 The Relationship Between Climate Change and Health

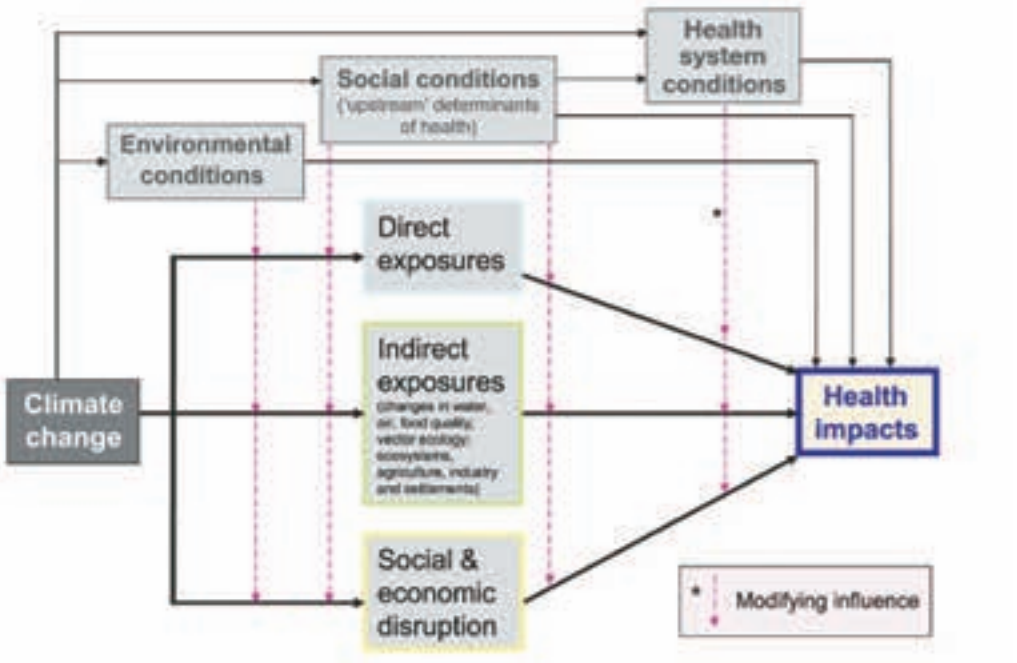
The World Health Organization's definition of human health as "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (WHO, 2006, p. 1) is widely accepted and has influenced the development of approaches to managing population health worldwide. In writing about the concept of health, Frankish et al. (1996) expand the discussion to include a person's capacity to adapt to, respond to, or control life's challenges and changes. It is now widely understood that at every stage of life, health is determined by complex interactions between social and economic factors, the physical environment, and individual traits and behaviours. These factors are called determinants of health, and their combined influence determines the health status of individuals and populations (Public Health Agency of Canada (PHAC), 2003).

Determinants of health

- Income and social status
- Social support networks
- Education and literacy
- Employment/Working conditions
- Social environments
- Physical environments
- Personal health practices and coping skills
- Healthy child development
- Biology and genetic endowment
- Health services
- Gender
- Culture

Climate is one of many factors that determine the status of population health, and special analyses are needed to understand the complex pathways by which climate change can affect human health. Many determinants of health can be affected by weather, climate variability or other environmental changes induced by climate. For example, in the aftermath of a major storm or flood, individuals can experience loss of employment income, interruption of support systems or health services, changes in diet, exposure to environmental contaminants and/or social unrest—all of which can, individually or in combination, affect an individual's health status. The relationship between climate and its impacts on health occurs through a range of pathways that vary in directness, scale and complexity (Figure 1.5).

Figure 1.5 Pathways by which climate change impacts health, and the concurrent influences of environmental, social and health system factors



Source: Confalonieri et al., 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability* (Figure 8.1)

Direct exposure

Extreme climatic events in many parts of the world in the past decade have provided momentum for the study of the direct impacts of climate on health. Catastrophic events have facilitated the collection of data and enhanced the statistical power of analyses. Although the long-term effects of sudden and short-term climatic events remain a challenge for health researchers, sensitivity to extreme temperatures is one of the better understood climate stressors of human health (McMichael et al., 2003; Riedel, 2004). Several recent studies confirm the impacts of extreme temperatures on mortality within populations, as well as varying vulnerabilities and thresholds related to health impacts (Rainham and Smoyer-Tomic, 2002; Kirch et al., 2005; Pengelly et al., 2005). The results of regional studies strongly suggest that social determinants (e.g. lifestyles, clothing, housing, social services) can affect mortality, and that local studies are important to understand specific vulnerabilities. As well, weather conditions are a direct contributing factor to motor vehicle accidents (Andrey et al., 2005). Although longer snow-free periods in southern Canada could reduce dangerous winter driving conditions, Andrey et al. (2005) indicated that the relative risks of mortality or serious injury are less during snowfall than those observed during rainfall or mixed precipitation.

Indirect exposure

Health impacts may also occur indirectly—as the result of changes induced by climate on biological (e.g. plants, organisms, animals) or geochemical (e.g. air composition) systems. These changes can alter conditions favourable for infectious diseases (water-, food-, vector- and rodent-borne diseases). For example, the establishment, reproduction and survival of insects and other hosts of diseases, such as tick-borne Lyme disease and mosquito-borne West Nile virus (Health Canada, 2005b), can be influenced by temperature and precipitation. Temperature is known to play a role along with other factors in the outbreaks of food-borne diseases in most temperate developed countries (Kovats et al., 2004a, 2004b). Water-borne disease outbreaks have been associated with heavy precipitation, spring snowmelt and flooding (Bowie et al., 1997; Rose et al., 2000; Curriero et al., 2001; Charron et al., 2004; Schuster et al., 2005; Thomas et al., 2006). Weather conditions can also affect air quality through the transport of air-borne pollutants, creation of ground-level ozone and production of pollens (McMichael et al., 2003; Garneau et al., 2005). There is a well-known association between levels of air pollutants and health effects within populations.

Climate change can also have an impact through economic and social factors such as the loss of employment or property after a natural disaster, resulting in stress and other illnesses. Climate change will also exacerbate the challenges already faced by many Canadian communities that rely on agriculture, forestry and other natural resource-based activities (Lemmen et al., 2008). Increased financial burdens on families and communities may affect many determinants of health, such as nutrition, housing conditions and sanitation, mental stress, marital stress, and substance abuse. Similar impacts have been observed in populations that experience catastrophic weather events.

Transportation is another aspect of Canadian society highly influenced by climatic conditions. For many northern residents, the unreliability of "snow roads" because of milder winters has substantial implications in terms of access to food, goods and services, and employment. Weather conditions can contribute to motor vehicle accidents; overall, casualty collisions cost the Canadian health care system more than $10 billion per year (Canadian Council of Motor Transport Administrators (CCMTA), 2001).

Globally as well as nationally, the balance of positive and negative health impacts will vary from one location to another, and will change over time, as temperatures continue to rise. In 2001, Health Canada adopted its own list of health effects from climate change as a preliminary guide for its investigation of the impacts of climate change on health in Canada; this list (Table 1.1) has been a useful reference for examining how understanding of the health effects of climate is advancing in Canada.

Table 1.1 Typical climate risks and related health effects

Health Impact Categories	Climate-related Causes	Projected / Possible Health Effects
Temperature extremes	• More frequent and severe heat waves • Overall warmer weather, with possible colder conditions in some locations	• Heat-related illnesses and deaths • Respiratory and cardiovascular disorders • Possible changed patterns of illness and death due to cold
Extreme weather events and natural hazards	• More frequent and violent thunderstorms, more severe hurricanes and other types of severe weather • Heavy rains causing mudslides and floods • Rising sea levels and coastal instability • Increased drought in some areas, affecting water supplies and agricultural production, and contributing to wildfires • Social and economic changes	• Death, injury and illness from violent storms, floods, etc. • Social and emotional injury and long-term mental harm from loss of loved ones, property and livelihoods • Health impacts due to food or water shortages • Illnesses related to drinking water contamination • Effects of displacement of populations and crowding in emergency shelters • Indirect health impacts from ecological changes, infrastructure damages and interruptions in health services • Psychological health effects, including mental health and stress-related illnesses
Air quality	• Increased air pollution: higher levels of ground-level ozone and airborne dust, including smoke and particulates from wildfires • Increased production of pollens and spores by plants	• Eye, nose and throat irritation, and shortness of breath • Exacerbation of asthma symptoms • Chronic obstructive pulmonary disease and other respiratory conditions • Exacerbation of allergies • Heart attack, stroke and other cardiovascular diseases • Increased risk of certain types of cancer • Premature death
Contamination of food and water	• Contamination of drinking and recreational water by run-off from heavy rainfall • Changes in marine environments that result in algal blooms and higher levels of toxins in fish and shellfish • Behavioural changes due to warmer temperatures resulting in an increased risk of food- and water-borne infections (e.g. through longer BBQ and swimming seasons)	• Outbreaks of strains of micro-organisms such as *E. coli, Cryptosporidium, Giardia, S. typhi* (typhoid), amoebas and other water-borne pathogens • Food-borne illnesses • Other diarrhoeal and intestinal diseases
Infectious diseases transmitted by insects, ticks and rodents	• Changes in the biology and ecology of various disease-carrying insects, ticks and rodents (including geographical distribution) • Faster maturation for pathogens within insect and tick vectors • Longer disease transmission season	• Increased incidence of vector-borne infectious diseases native to Canada (e.g. eastern & western equine encephalitis, Rocky Mountain spotted fever) • Introduction of infectious diseases new to Canada • Possible emergence of new diseases, and of those previously eradicated in Canada
Stratospheric ozone depletion	• Depletion of stratospheric ozone by some of the same gases responsible for climate change (e.g. chloro- and fluorocarbons) • Temperature-related changes to stratospheric ozone chemistry • Increased human exposure to UV radiation owing to behavioural changes resulting from a warmer climate	• More cases of sunburns, skin cancers, cataracts and eye damage • Various immune disorders

Source: Adapted from Health Canada, 2005b.

1.3.2 Determining Who Is at Risk

Vulnerabilities within a population are generally uneven. Some individuals or groups may be more sensitive or more exposed to a climate hazard, and others may have a greater capacity to cope. Identifying different sensitivities within the population (e.g. age, culture, occupation, location) and the variations in exposure to these risks are key aspects of climate and health research. It is also well documented that coping strategies play an important role in reducing the vulnerability of individuals and populations to a variety of hazards (IPCC, 2007a; McMichael et al., 2003; Menne and Ebi, 2006).

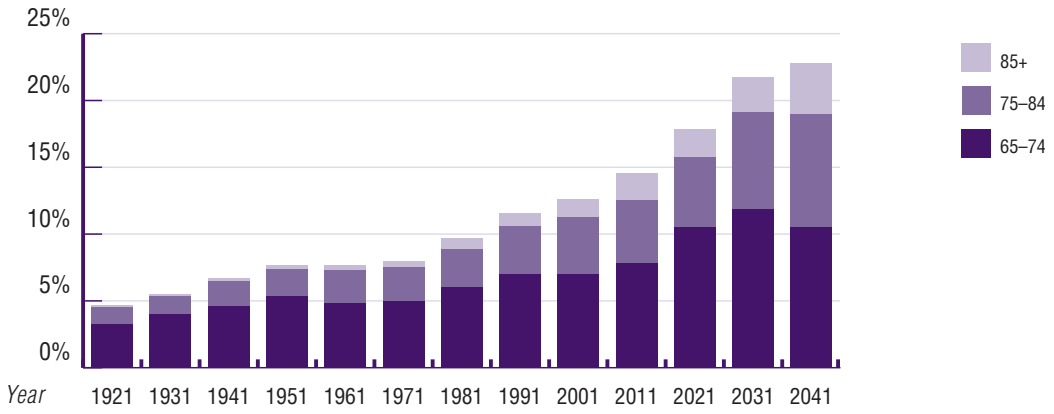
On the whole, Canadians enjoy very good health status. Statistics Canada (2006) reported that Canadians' life expectancy reached 80.2 years in 2004 compared with 74.9 years in 1979. Worldwide, Canada has one of the lowest rates of low birth weight at 5.3 per 1,000 live births. More than half (58.4%) of Canadians reported having very good or excellent health. Canadians also enjoy a relatively high level of health services; in 2001, 87.7% of Canadians had a regular family physician and 84.4% of Canadians thought the health services they received were of excellent or very good quality (Health Canada, 2002).

The high level of population health in Canada provides a strong foundation for coping with the diverse stresses that climate change will place on health and well-being. Healthy populations are more resistant to infection and disease, better able to recover from injury and less likely to fall ill under difficult conditions. However, there are notable disparities within Canada's general population. For example, Aboriginal populations experience poorer health, lower life expectancies, higher rates of some chronic illnesses as well as significant socio-economic disparities (unemployment, education, average income) (Health Canada, 2005a). Children and infants are more vulnerable to water- and food-borne illnesses because of the immaturity of their immune systems and inadequate ability to avoid the risks (Pond, 2002). Resource-dependent and remote communities have fewer resources available for coping and limited access to a wide range of services (Lemmen et al., 2008). Understanding the disparities within the Canadian population is a key aspect in studying how people may be sensitive to climate change and proposing solutions that will protect the most vulnerable.

Successive national censuses have shown a Canadian population in evolution. Future demographic characteristics will include a marked increase in the proportion of seniors in Canada[2] (Figure 1.6), a continued increase in life expectancy, an increase in immigrant populations, a growing trend toward obesity and poor physical fitness, and an increasing proportion of people living in urban centres. All these need be examined in the context of the impacts of climate change on health and society.

2 For the purposes of the Assessment, *seniors* refer to people over the age of 65.

Figure 1.6 Seniors by age sub-group, as a percentage of total population, Canada, 1921 to 2041



Source: Government of Canada, 2002.

Increase in population of seniors

The proportion of seniors increased from 10 to 13% of the Canadian population between 1981 and 2005, and is projected to almost double in the next 25 years. According to medium-growth scenarios, half of the Canadian population will be over 47 years of age by 2056. The proportion of the oldest persons (80 years and older) is also likely to increase sharply, such that by 2056, 1 in 10 Canadians will likely be 80 or more years of age, compared with 1 in 30 in 2005 (Statistics Canada, 2005).

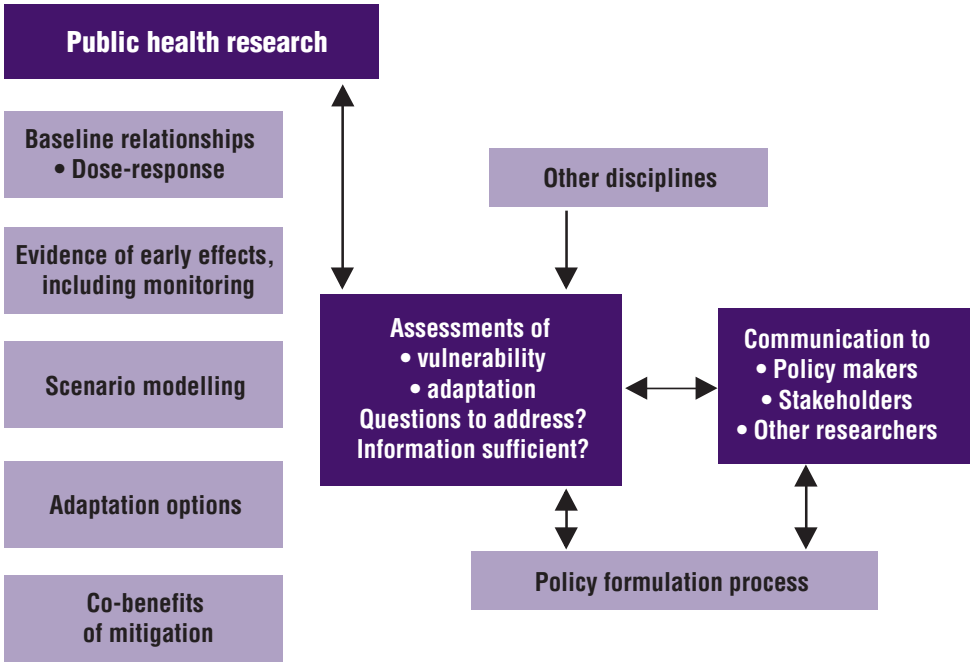
Every individual in Canada can be exposed to climatic stresses, but where you live, your occupation, existing health status and available resources can make a difference to your vulnerability to these stresses. Several well-documented vulnerabilities are relevant to the study of the impacts of climate change on health. Infants and children are especially vulnerable to environmental degradation because of their inability to protect themselves, relatively high intake of water, air and certain foods, rapid growth and development, immature physiology and metabolism, and potential for high cumulative exposures over their lifetime (Wigle, 2003). Recent Canadian research indicates that pregnant women and their developing fetuses may be at special risk during extreme weather events (Laplante et al., 2004). Women may be more vulnerable to psychosocial health impacts during extreme weather events because they are more likely to bear the burden of recovering from the event and of continuing to meet multiple demands within and outside the household (Elliot, 2001; Enarson, 2001). An established body of Canadian and international research provides strong evidence that age is a risk factor for heat- and cold-related mortality (Koppe et al., 2004; Menne and Ebi, 2006). Seniors are more vulnerable to heat because of age-related changes to their regulatory system and/or because they are taking drugs that interfere with normal homeostasis (Koppe et al., 2004).

Social factors also contribute to vulnerabilities. A few studies discovered that older men suffer more from isolation, and as a result may be vulnerable to climatic extremes because they do not have the ability to seek the assistance of family members or community volunteer organizations (Klinenberg, 2002; Soskolne et al., 2004). People in poor health, with precarious living conditions and limited economic means will generally have more difficulties coping with environmental stresses. Certain occupations may be affected by increased temperatures, extreme weather events and poor air quality. Those who live on the land and whose livelihood is tied to natural-resource-based employment will also be affected in unique ways (Riedel, 2004; Berner et al., 2005). The broad spectrum of potential physiological sensitivities and vulnerabilities highlights the importance of population-specific studies.

1.3.3 Studying Climate Change and Health: Approaches and Challenges

Climate change and health researchers have applied known methods and developed new approaches to take into account the complexity of interactions between climate variables and the determinants of health, the challenges of scale, the uncertainties inherent in all the systems under study and the many coping strategies that may be employed by those at risk. The World Health Organization has outlined five main tasks for researchers of health and climate change: (1) establishing baseline relationships between weather and health, (2) seeking evidence of early effects of climate change, (3) developing scenario-based predictive models, (4) evaluating adaptation options, and (5) estimating the coincidental benefits and costs of mitigation and adaptation (McMichael et al., 2003) (Figure 1.7). Where data and research were available, analysis in the Assessment was structured according to these tasks.

Figure 1.7 Tasks for public health science



Source: McMichael et al., 2003.

Epidemiological studies have been useful in establishing baseline relationships between weather and health. However, standard methods have proven to have limited applicability in seeking evidence of the early effects of climate change; this is because broad-scale effects and indirect causal pathways over long time spans and a broad geography need to be examined. Some of these challenges are amplified when dealing with smaller populations, such as in Canada's North. Researchers also routinely face important challenges with respect to the completeness, comparability and usability of available data. Matching climate or meteorological data and environmental quality and health data for the desired time or geographical scale is not always possible.

Using scenario-based predictive models to estimate health outcomes for a future climatic regime is a practice still in its infancy, but it is becoming more sophisticated. Health researchers have a choice of several predictive models that present future climate scenarios, based on varying levels of GHG emissions. The task is to link these models with health impact models where health impacts can be readily estimated. Not all health outcomes are easily quantified or modelled (e.g. the effects of climate change on nutrition in northern Canada or the perinatal effects of extreme weather events). Without evidence of health outcomes at the population level, some of the impacts of climate on health are difficult to integrate into models forecasting multi-outcome health risks of climate change (McMichael et al., 2003). For this reason, assessments provide an opportunity to bring together knowledge derived from different methods to better understand the multitude of effects and possibilities for adaptation.

Assessing the impacts of climate change on health is challenging because health outcomes are strongly influenced by many determinants (e.g. behavioural factors, socio-economic factors, public health infrastructure). However, the understanding of causal pathways as well as the sensitivity of different populations to a range of climate-related risks has evolved significantly in the past decade in Canada and the rest of the world. The understanding of the relationship between climate and health is only the first step in identifying the potential risks and population vulnerabilities to climate change. In order to inform adaptive strategies and reduce future health risks, it is necessary to assess whether there will be an increase in the population exposed, whether coping strategies are adequate or whether such an increase will result in greater incidence of disease, illnesses or mortality. An even greater challenge for health decision makers and researchers is the consideration of the effects on population health of a sequence or cumulation of events and conditions. Overall, data on health effects and vulnerabilities across populations are necessary to devise cost-effective and successful adaptation options, but the valuation of health costs and benefits can also be a useful and sometimes necessary input to the calculation of costs and benefits of GHG reduction initiatives. Comprehensive assessments such as this one can demonstrate the breadth of co-benefits to health from actions to address climate change.

At this time, considering the uncertainties of climate projections, the presence of confounding factors and limits to the knowledge of environmental effects on health, many researchers and decision makers have approached its study in manageable parts, focusing on regional interests and priorities. By sharing findings and results, knowledge of climate-health relationships is continually improving, and the areas and conditions that create vulnerabilities for certain people within the Canadian population are being increasingly identified.

1.4 ADAPTIVE CAPACITY AND ADAPTATION

1.4.1 Understanding Adaptive Capacity

As knowledge of the interactions between climate and health risks and the identification of vulnerable populations (sensitivity) grows, attention is being paid to understanding the mechanisms and strategies that protect health or create barriers to adaptation. Perception of risks and of how well equipped people are to deal with them are important aspects of the coping capacity of individuals and institutions. The challenge of adapting to climate change is taking action in anticipation of an event or events for which there are significant uncertainties with regards to the time of occurrence, scale or other essential parameters. Investigating adaptive capacity and adaptation is less structured than the study of other aspects of climate change and draws on social sciences and humanities disciplines to inform its investigative processes.

Adaptive capacity

Adaptive capacity refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences (IPCC, 2007a).

Adaptive capacity is influenced by many interrelated societal factors, such as economic resources, technology, information and skills, infrastructure, institutions, existing inequities in health status and pre-existing disease burdens (Grambsch and Menne, 2003). Countries will generally have greater adaptive capacity when they have higher levels of gross domestic product or financial capital, substantial per capita investments in health care, access to technologies such as vaccines or water treatment facilities, high levels of human capital or knowledge (e.g. health research), well-developed public health infrastructures, well-established social institutions, equitable access to health care and social supports, and overall population health and well-being (Yohe and Tol, 2002; Adger, 2003).

It is easy to take for granted the measures that protect the health of Canadians from climate extremes and other environmental hazards. These safeguards include safe water (treatment); air and food regulations; adequate income; housing and clothing to handle environmental conditions such as temperature and pests; high-quality civil infrastructure such as storm sewer, drainage and sanitation systems; and also all health infrastructures and services, including disease surveillance, public health programs and vaccination. When any of these public health services fail to meet their required standards, or are compromised—as is possible in a changing climate—good health is endangered. It is important to understand how these services will perform under different conditions and to identify adjustments needed to ensure good health when the climate is changing so rapidly.

1.4.2 Toward Adaptation

Recent events in Canada and abroad have shown that developed countries can be overwhelmed by climatic events. Losses from wildfires, floods, storms and droughts occur annually in Canada, amounting to hundreds of millions of dollars (PSEPC, 2005). Two multi-billion dollar disasters occurred in the 1990s—the 1998 Ice Storm ($5.4 billion) and the 1996 Saguenay flood ($1.7 billion) (PSEPC, 2005). But the impact of these events on the health and well-being of affected populations goes beyond the reported monetary costs. Recent studies of health vulnerabilities in Canadian populations have provided insights into how impacts can affect health in the short and long term. Although knowledge is far from complete, adaptive strategies to protect public health from the impacts of climate change will be needed. Well-informed individuals and institutions are essential to making long-term sustainable decisions and to protecting those populations most vulnerable to the risks associated with climate change.

The reduction of GHG emissions is important to limiting the rate and magnitude of future climate change. Nevertheless, even if global efforts to reduce GHGs are successful in the future, climate change and its associated impacts are now expected to be unavoidable (IPCC, 2007c). Consequently, current and future health vulnerabilities arising from different climatic scenarios must be assessed, and options for effective interventions and adaptations must be identified. The assessment process is a way to determine where action is needed, and how to integrate that knowledge of the future into current plans and activities.

For industrialized countries with high levels of education and health status, and well-developed infrastructures and health care systems, the task is largely to improve on existing processes and programs using new climate and health information. Consideration is also needed about how climate change will compound other environmental, social and economic changes to bring about unmanageable stresses to these systems. The study of adaptation must include an understanding of the effectiveness of systems that are already in place to help manage health risks (e.g. smog alerts, heat and cold alerts, severe weather warnings, boil water advisories, disease and health surveillance, emergency preparedness and response, health services). It must also consider the sensitivity to climate, the surge capacity and resiliency of these systems in order to determine if adjustments are required to ensure continued effectiveness. Awareness and education also play a role in ensuring that individuals adopt appropriate behaviours in the face of new risks.

Experience has shown that catastrophic events can be catalytic in bringing about actions to strengthen the ability of individuals and institutions to deal with similar events in the future. For example, in the province of Quebec, the 1998 Ice Storm that affected eastern Canada played a crucial role in building up momentum to increase the capacity to cope with extreme weather. It also created a society that is more aware today of its vulnerabilities to current climate variability and future climate change because of targeted research investments, policy development and awareness building. Decision makers in many sectors, such as forestry, agriculture, health and industry, are now able to integrate this new information into current risk management regimes and planning activities (Desjarlais et al., 2004).

It is important to recognize that regions of the world already facing significant sustainability challenges are hit the hardest by climatic change. Canada can share its knowledge, expertise and resources to help others reduce their vulnerabilities and build strong and healthy societies. Adaptation can be successful if it is guided by reliable knowledge of the vulnerabilities to climate change and sound assessments of their implications for current systems of managing risks. Our hope is that communication and discussion of the findings of this Assessment among decision makers and stakeholders can inform and support adaptation processes in Canada and around the world.

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