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Human Health in a Changing Climate:

A Canadian Assessment of Vulnerabilities and Adaptive Capacity

Synthesis Report

Canada

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Cover photo of Hurricane Juan damage courtesy of Doug Mercer, Meteorological Service of Canada

PREFACE

Human Health in a Changing Climate is the first study of its kind in Canada. It provides an up-to-date synthesis of knowledge on how the health of Canadians is affected by the climate today, and what lies ahead under future climate change. Through an examination of key health issues of concern, along with two regional assessments (the province of Quebec and Canada's North), it develops a baseline of evidence concerning the relationship between a changing climate and direct as well as indirect impacts on health. A framework for analyzing adaptive capacity is presented, along with an exploration of how governments, communities and individuals are drawing on current capacity to address and mitigate the effects of climate on health. Each chapter makes recommendations for future action and identifies key knowledge gaps to direct future research in support of adaptation to protect the health of Canadians.

Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity

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OVERVIEW

Climate change is expected to increase risks to the health of Canadians through many pathways: the food they eat, the air they breathe, the water they drink, and their exposure to extreme weather events and infectious diseases found in nature. Adaptation helps us prepare now for the expected changes by taking proactive actions to minimize risks. Understanding existing health vulnerabilities in society and among specific population groups allows decision makers within and outside of the health sector to target their resources, policies and program priorities in order to better protect Canadians. The following points represent key conclusions from this assessment of risks to health from climate change.

- The *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC), released in 2007, confirms that climate change is occurring and impacting a range of natural and human systems both within and outside of Canada.
- Climate change scenarios project an increased risk of extreme weather and other climate-related events in Canada such as floods, drought, forest fires and heat waves—all of which increase health risks to Canadians.
- The air Canadians breathe is affected by climate. Air quality in many Canadian communities is likely to be affected by climate change through increased smog formation, wildfires, pollen production and greater emissions of air contaminants due to changed personal behaviours—all increasing risks to health.
- Climate change is likely to increase risks associated with some infectious diseases across the country, and may result in the emergence of diseases that are currently thought to be rare in or exotic to Canada.
- Like other Canadians, Quebeckers face several risks to health from climate change. Historically, they have adapted well to very cold temperatures but have not been as successful in adapting to extreme heat. As average temperatures continue to increase, the number of heat-related deaths in Quebec will also increase, without further adaptations.
- Northerners are already reporting environmental changes and corresponding risks to health and well-being associated with a changing climate, and are taking many actions to adapt. Key vulnerabilities exist where individuals or communities in the North are already highly exposed to health risks, and where exposure is likely to increase with changing climatic conditions.
- Overall, Canadians enjoy very good health status and a high level of health and social services, providing a strong foundation for coping with the diverse stresses that climate change will place on health and well-being. However, the combined effects of projected health, demographic and climate trends in Canada, as well as changes related to social conditions and infrastructure, could increase the vulnerability of Canadians to future climate-related health risks in the absence of effective adaptations.
- Concerns exist about the effectiveness of current adaptations to health risks from climate variability. Existing gaps in public health and emergency management activities that are not addressed have the potential to significantly affect the ability of Canadians to effectively plan for and respond to climate change in Canada.
- Adaptation can reduce health risks posed by climate change by providing citizens with the knowledge, tools and confidence needed to take protective actions. Measures to protect health should be tailored to meet the needs of the most vulnerable Canadians—seniors, children and infants, the socially disadvantaged, and the chronically ill.
- Barriers to adaptation exist in Canada and include an incomplete knowledge of health risks, uneven access to protective measures, limited awareness of best adaptation practices to protect health, and constraints on the ability of decision makers to strengthen existing health protection programs or implement new ones.
- Adaptive capacity is not evenly distributed among communities in Canada. Small communities often have less capacity to plan for or cope with the effects of extreme events or health emergencies.
- The health sector needs to maintain current efforts to protect health from climate-related risks, and incorporate climate change information and engage other sectors in their plans for future programs.
- Regional and community-level assessments of health vulnerabilities are needed to support adaptation through preventative risk reduction.
- Multi-disciplinary research and collaborations across all levels of government can build the knowledge base on vulnerabilities to climate change to address existing adaptation gaps.

INTRODUCTION

Human Health in a Changing Climate was conducted in response to an identified need to understand the significance of climate change for the health of Canadians. More specifically, an assessment was necessary to provide the information required to set directions for research, policies and adaptive actions. This Assessment brings together information collected using a wide range of methods and comprises investigations at both national and regional scales. It integrates findings from recent studies on climate change, many of which are the result of work conducted by Canadian health researchers, supported by contributions from international scientists and experts from many disciplines and fields. Decision makers in all regions can find information on approaches for conducting vulnerability assessments and draw lessons from the two regional assessments conducted for this report. It also offers research directions and advice for adaptation decisions at all levels of government aimed at reducing risks to health.

This Synthesis Report sets out the key findings of the Assessment and presents important issues common to each of the chapters: how climate-related health impacts affect Canadians today, how climate change may influence health risks in the future, which Canadians are most vulnerable to these risks, and what adaptive strategies can protect public health from climate change. It is intended for officials at all levels of government including program managers and practitioners working in the areas of public health, health care delivery, emergency management, and community social services. Information and conclusions presented in this document are drawn from the fully referenced Assessment Report.

The Synthesis does not include an overview of basic climate change science, or information about the full scope of the anticipated impacts of climate change in Canada, or its regions. A comprehensive study, *From Impacts to Adaptation: Canada in a Changing Climate 2007*, reports on the body of knowledge regarding how climate change affects our country. In each regional chapter, current and anticipated impacts are reported, with a focus on ecosystems and managed systems. Key concerns about health impacts are reported in the context of a wide range of risks to Canadians in each region of the country.

Human Health in a Changing Climate complements this study by providing decision makers with an integrated perspective on existing vulnerability to the potential health impacts of climate change, and insights on how risks can be reduced by increasing adaptive capacity. It provides information to support collaborative efforts by federal, provincial, territorial and municipal governments, by public health and emergency management organizations and by individuals to protect health in the face of a changing climate. For those who wish to consult the full Assessment, it can be ordered by contacting Health Canada Publications at info@hc-sc.gc.ca.

The Assessment is organized as follows:

Chapter 1, *Introduction*, describes the origins, scope and organization of the Assessment and provides information on climate change in Canada to support the understanding of the relationship between health and a changing climate. An introduction to adaptive capacity and adaptation concludes the presentation of concepts that are common to all the chapters of the Assessment.

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 and measures 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, *The 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.

Key terms used in *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity*

Adaptation – Adjustment in natural or human systems in response to actual or expected effects of climate change and variability, which moderates harm or exploits beneficial opportunities. Various types of adaptation exist (e.g. anticipatory and reactive, private and public, autonomous and planned).

Adaptive Capacity – 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.

Climate – Climate in a narrow sense is usually defined as the average weather. It is also defined in statistical terms as the mean and/or variability of relevant variables over a period of time ranging from months to thousands or millions of years.

Climate Change – Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.

Determinants of Health – At every stage of life, health is determined by complex interactions between social and economic factors, the physical environment and individual behaviour. The determinants of health include 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 and culture.

Disaster – An event that exceeds the ability of the local community to cope with the harmful effects and requires extraordinary response and recovery measures.

Extreme Weather Events – An event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. Examples of extreme weather events include floods and droughts.

Mitigation (climate change) – In the context of climate change, mitigation is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.

Prevention – A method of averting health problems (e.g. disease, injury) through interventions. Preventing and reducing the incidence of illness and injury may be accomplished through three mechanisms: activities geared toward reducing factors leading to health problems; activities involving the early detection of, and intervention in, the potential development or occurrence of a health problem; and activities focusing on the treatment of health problems and the prevention of further deterioration and recurrence.

Urban Heat Island Effect – The effect whereby a region within an urban area is characterized by ambient temperatures higher than those of the surrounding area because of the absorption of solar energy by materials like asphalt.

Vulnerability – Vulnerability to climate change is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.

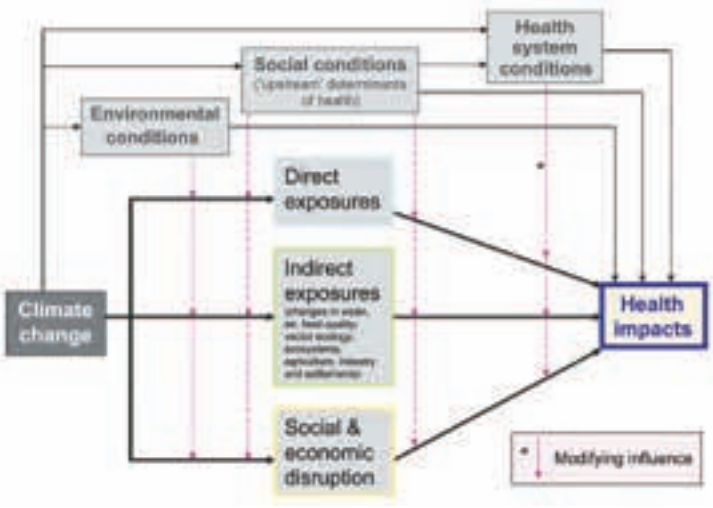
Weather – Weather is the state of the atmosphere at a given time and place with regard to temperature, air pressure, humidity, wind, cloudiness and precipitation. The term "weather" is used mostly for conditions over short periods of time.

CLIMATE IS A KEY DETERMINANT OF HEALTH

It may be obvious to most that the weather conditions that, over time, constitute the climate can impact the health of Canadians. From the first inhabitants of this land, people have developed technologies and adopted behaviours enabling them to survive in a variable and often harsh climate. Because the relationships between climate and human health follow multiple pathways and are complex, it is necessary to have a thorough understanding of climate-related health risks that Canadians face today so that it can be possible to effectively address the impacts of climate change on human health.

Human health has been defined as "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity."[2] At every stage of life, health is influenced by complex interactions among a number of determinants: social and economic factors, biology and genetic endowment, health services, education and literacy, gender and culture, the physical environment and personal health practices and coping skills. Climate is one of many factors that can affect health, and special analyses are required to understand the pathways by which climate, and climate change, can have such impacts. Social and environmental factors that may influence other health determinants are part of the pathways that mediate between climate-related risks and potential negative health impacts (Figure SR–1).

Figure SR–1: 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).

Climate can affect the health of individuals through both direct and indirect exposures. Examples of health impacts from *direct exposures* include deaths and injuries resulting from violent storms and illnesses and distress related to extreme heat events. Less well understood are the economic and social determinants that contribute to individual or population vulnerability, as well as the long-term health effects of direct exposures. Health impacts from *indirect exposures* are the result of changes induced by climate on other systems, for example, by creating conditions favourable to the occurrence of infectious disease outbreaks from food or water contamination, or the formation of smog.

2 World Health Organization, 2006.

Table SR–1: Health impacts, their climate-related causes and typical 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 wild fires • 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 wild fires • 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, 2005.

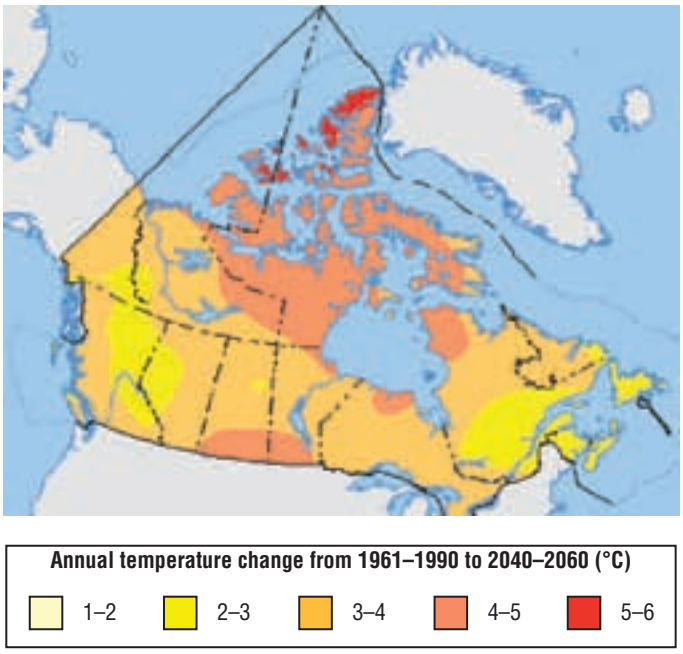
CLIMATE CHANGE PROJECTIONS FOR CANADA

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. The *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC), released in 2007, confirmed the observed trends, including an unprecedented rate of warming, widespread retreat of glaciers, rising sea levels, changes in the frequency and severity of some types of extreme weather events (e.g., floods, droughts, severe storms, and heat waves) and a wide range of impacts on both natural and human systems.

The IPCC report also includes a review of the health effects of climate change worldwide. It concludes that climate change, and specifically changes in temperature and precipitation levels, have already led to impacts on human health. It also outlines a wide range of expected impacts on economies, and physical and social environments in every region of the world. Canada is no exception. In Canada, average national temperatures have increased 1.2°C over the past 50 years and an even more rapid rate of warming is projected over this century. Observed warming has been greater at northern latitudes and it is projected that Canada will continue to experience higher rates of warming in this century than most other countries in the world. The Yukon and the Northwest Territories are now experiencing the most warming, and Canada's Arctic and central Prairie region are projected to have the highest temperature increases in the coming decades (Figure SR–2).

Across the country, the percentage of precipitation that falls in heavy events is increasing. While this trend is projected to continue in the future, some areas will experience less precipitation during the growing season with longer periods of little precipitation overall. There is, however, a higher degree of uncertainty concerning projections of climate parameters such as precipitation, cloud cover and winds, than temperature changes.

Figure SR–2: A simulation of projected changes in annual mean temperatures for the period 1961–1990 to 2040–2060



Source: Atlas of Canada, 2003.

In turn, projections about future warming for the North American continent are made with a higher level of confidence than the projected regional variations in the temperature changes. Canadian scientists are contributing to the development and refinement of regional climate projections of changes for the 21st century, which will provide information for better regional- and local-scale studies to more precisely determine risks and vulnerabilities to human health. As the results of studies at finer scales become available, it will be possible to improve the analysis of potential health impacts to better inform development of adaptation strategies and actions at regional and local levels.

CLIMATE RISKS TO HEALTH: NOW AND IN THE FUTURE

In Human Health in a Changing Climate three key pathways through which climate currently affects health are examined—weather-related natural hazards, effects of climate on air quality and climate influences on diseases transmitted by water, food, vectors (insects and ticks) and rodents—along with how associated health risks may change under different climate conditions.

Extreme weather events and natural hazards

All Canadians are exposed to extreme weather and natural hazards and can experience their effects. But risks vary considerably depending on where a person lives, their personal behaviour, their sensitivity to the impacts, and ability to take protective actions. The scope of weather-related hazards across Canada that impact health is quite broad, ranging from heat waves, cold snaps, floods, droughts, wild fires, tornadoes, freezing rain and ice storms, to thunderstorms, hurricanes and avalanches (Table SR–2). Some hazards, such as flooding, have affected people in all regions of Canada. Others, such as hurricanes, are a threat in only a few regions. Most communities and regions can also be at risk from more than one hazard. Several events occurring at once, or in quick succession, can easily overwhelm the capacity of communities and individuals to respond and return to normal.

Table SR–2: Regions in Canada affected by natural hazards[3]

Hazard	Most Affected Areas
Avalanches, Rock- Mud- and Landslides, Debris Flows	All regions of Canada—particularly Rocky Mountains in Alberta, British Columbia, Yukon, southern and northeastern Quebec and Labrador, Atlantic coastline, Great Lakes, St. Lawrence shorelines
Heat Waves	All regions of Canada—particularly Windsor to Quebec corridor, along Lake Erie, Lake Ontario and St. Lawrence River, Prairies, Atlantic Canada, British Columbia
Cold Snaps	All regions of Canada
Drought	Prairie provinces most affected Other areas of southern Canada can be at risk
Wild fires and Forest Fires	Most provinces and territories of Canada—particularly Ontario, Quebec, Manitoba, Saskatchewan, British Columbia, Northwest Territories, Yukon
Thunderstorms, Lightning, Hail, Tornadoes, Hurricanes	Thunderstorms: Many regions of Canada Lightning: Low-lying areas in southern Canada Tornadoes: Nova Scotia, Ontario, Quebec, Alberta, Saskatchewan, Manitoba Hurricanes: Eastern Canada—particularly Atlantic Canada Hailstorms: Southern Saskatchewan, southern and northwestern Alberta, southwestern interior British Columbia, less frequently in Ontario and Quebec
Floods	Large parts of Canada's inhabited areas—particularly New Brunswick, southern Ontario, southern Quebec, Manitoba

The Canadian Disaster Database provides an important source of information concerning the occurrence and impacts of large-scale events in Canada. During the past century, fatalities from natural hazards and extreme weather events in Canada have decreased largely due to improvements in infrastructure, knowledge of existing risks, and protection measures that have been implemented. However, the number of people affected and the associated economic costs from such events have shown a dramatic increase in recent decades. The total number of Canadians affected by natural disasters increased from 79,066 between 1984 and 1993, to 578,238 between 1994 and 2003. There is also some evidence of increases in communicable diseases and longer-term psychological and social effects in the aftermath of extreme weather events.

3 The table includes information from the Canadian Disaster Database to highlight where most weather-related disasters have occurred in the past. Risks to health from natural hazards may exist in regions where disasters have not occurred, so this table likely underestimates current exposure by Canadians across the country to these types of events.

Figure SR–3: Number of Natural Disasters in Canada, 1900–2002

Source: Etkin et al., 2004.

Across Canada, injuries, evacuations and economic losses from climate-related disasters in Canada are on the rise. Recent events such as the 1996 Saguenay Flood, the 1998 Ice Storm in eastern Canada, Hurricane Juan in 2003 and the 2005 flood in Toronto have shown that climate variability can overwhelm infrastructure, disrupt communities and cause irreversible damage to ecosystems.

Existing data in the Canadian Disaster Database which includes deaths, injuries, economic costs, evacuation and homelessness provide an incomplete picture of the health impacts on people and costs to health care systems.

Challenges exist in acquiring health data, particularly in relation to short-term and unexpected events. Only for a few events that occurred in Canada is information available on the health and well-being of individuals and the progress toward recovery of their community months or years later. These long-term effects tend to be recorded through individual case studies and are most often related to disasters and other large-scale events. As a result, effects on mental health, chronic illnesses, and utilization of health care services are underestimated in Canada.

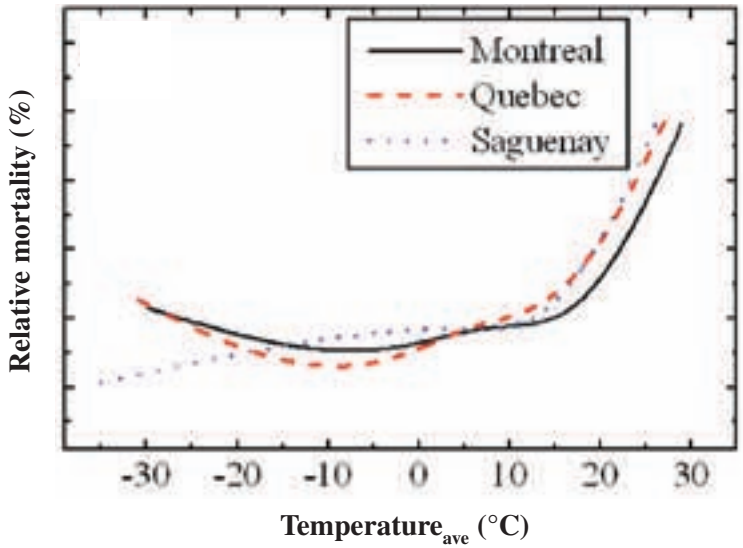
Extreme heat events pose significant risks to individuals and can be especially dangerous for children and infants, seniors and people in frail health, particularly those taking certain medications. Few studies of temperature-related mortality have been carried out in Canada. The Quebec chapter examined historical levels of mortality in that province and found that they were associated with changes in ambient temperatures (Figure SR–4). For all cities and regions, there seems to be a point beyond which the number of deaths increases almost linearly with temperature. However, there is also the absence of a comparable rise in mortality under very cold conditions on a historical basis. The apparent success of current adaptations to cold temperatures in Quebec may reduce the expected future health benefits of climate change from reduced winter mortality that have been projected for Canada in international studies.

Health and emergency management authorities and organizations in Canada undertake a range of activities to reduce risks to Canadians from extreme weather events

Table SR–3: Natural Hazards and the Health of Canadians

- Between 1900 and 2005, five major heat waves occurred in Canada (1912, 1936, 1953, 1963, 1988) causing over 1,900 deaths.
- From 1912 to 2005, 31 disasters were caused by tornadoes in Canada which caused 142 deaths, injured 1,930 people and required the evacuation of nearly 6,500 people.
- Between 1950 and 2003 the Maritimes, Ontario and Quebec were subject to 16 violent storms originating from hurricanes, while the West Coast experienced two violent storms originating from typhoons. These storms caused extensive damage and 137 deaths.
- 52 nationally significant forest fires occurred in all provinces and territories in Canada between 1900 and 2005. Forest fires during that time forced the evacuation of at least 44 communities and more than 155,000 residents and caused the deaths of at least 366 people.
- The number of flood disasters along Canadian rivers seems to be on the rise, with 70% of floods over the past century occurring after 1959.
- Between 1950 and 2000, Canada experienced at least 37 major droughts, about two thirds of which occurred in the Prairie provinces. While no deaths were attributed directly to the droughts they caused several billion dollars in damage and impacted many communities.

Figure SR–4: Temperature-mortality relationships for Montreal, Quebec City and the Saguenay region



including hazard identification and assessment, the implementation of early warning systems, the provision of health emergency services, and public outreach campaigns to increase levels of preparedness among Canadians. For example, the Expect the Unexpected Program delivered by the Canadian Red Cross is a school-based program that educates children on the risks of natural disasters and how to stay safe in such events.

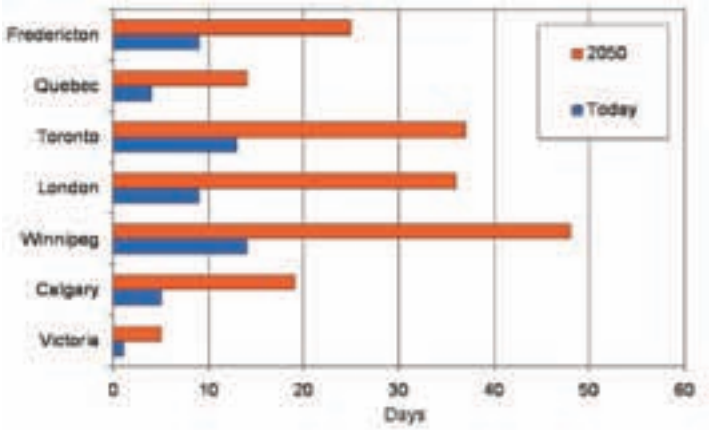
Future risks to human health

Even though it is not possible to predict the occurrence of individual extreme weather events before the conditions that spawn them form, climate change scenarios project an increased risk of extreme weather and other climate-related events (with the exception of extreme cold) for all regions of Canada. More floods are projected to occur in Canadian communities due to an increase in intense precipitation events, while the risk of drought and forest fires is also projected to increase. Many coastal areas will face greater risks from extreme weather events, such as stronger storm surges, and a decrease in the winter sea ice which protects coastlines. Heat waves are very likely to increase in frequency and severity, with the risk of heat-related deaths being the greatest in cities due to higher population densities and the urban heat island effect. In addition to increased risks from events that have affected some regions in the past, climate change may also pose threats from climate-related hazards that have not been experienced in a region previously, or have never occurred on a scale that has seriously disrupted a community or impacted human health. Historical experience with natural hazards is often related to levels of preparedness. Therefore, the introduction of new, or more severe hazards into some Canadian communities is a cause for concern about potential impacts on health.

Research undertaken for this Assessment modelled the relationship between future temperatures and mortality in Quebec. Using historic models with data from a mid-range climate model (based on IPCC scenarios A2 and B2 which assume a continuing trend of rising greenhouse gas emissions with a doubling of CO_2 circa 2080), the models projected increases in summer mortality and slight decreases in winter mortality. The projected net increase in annual mortality related to temperature in Quebec in 2020 is approximately 150 excess deaths per year, 550 deaths per year by 2050 and 1,400 deaths per year by 2080.

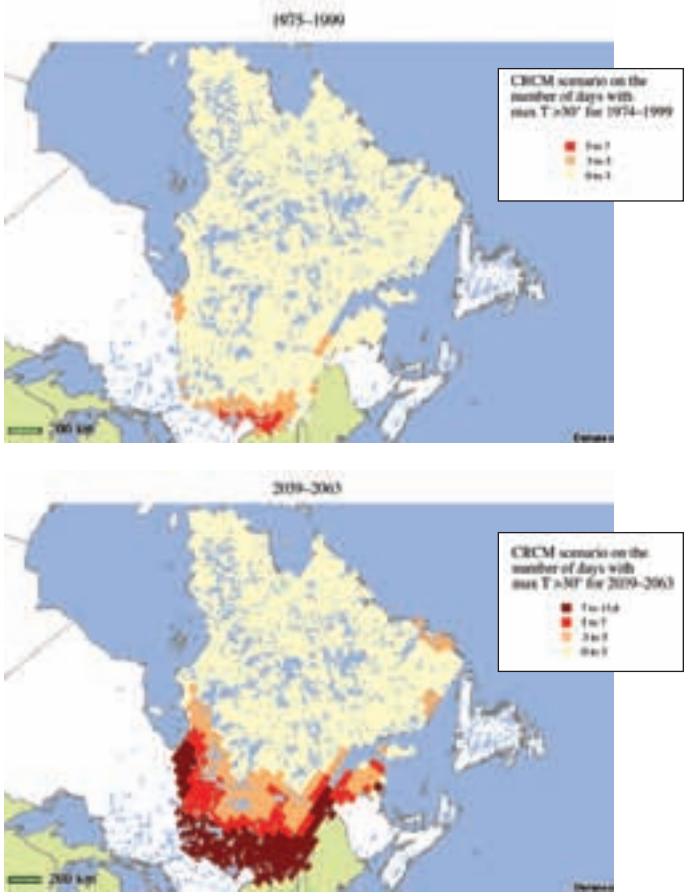
While future summer mortality rates associated with high temperatures are projected to be higher for all age groups, it is expected that the increase for the 65-and-older population cohort will be approximately two to three times greater than for individuals aged 15 to 64. This suggests that seniors are more vulnerable than younger adults to the health impacts of higher temperatures, which accords with the results of studies elsewhere in the world, in particular, Europe and the United States. These effects within the population can also be expected to be magnified by the expected increase in the number of seniors in future decades as well as the projected increase in the frequency and severity of heat waves (Figures SR–5 and SR–6). However, these projections do not take into account new measures and adaptive behaviours that can be implemented to reduce health risks to people living in Quebec, particularly those most vulnerable to the impacts.

Figure SR–5: Current and projected number of hot days above 30ºC for selected cities across Canada



Source: Hengeveld et al., 2005.

Figure SR–6: Current and simulated annual average number of hot days in Quebec



Note: Hot days are those with maximum temperature >30°C.

Source: Based on the Canadian Regional Climate Model (CRCM v3.6.1) and the IPCC IS92a emissions scenario, and conducted by the Ouranos Consortium in 2005.

Air quality and heat

Increases in mean global temperatures can affect air quality in Canada by increasing the formation of ground-level ozone, the production of pollens and other aeroallergens, and the number of wild fires. To understand impacts on the health of Canadians it is necessary to consider the effect of combined exposures to extreme heat and air pollution episodes.

Changes to local weather patterns and higher average temperatures can affect local and regional air pollution levels by trapping pollutants and altering the rates of atmospheric chemical reactions involved in the formation of ground-level ozone. In addition, emissions from natural

sources, such as nitrogen oxides released from soils and volatile organic compounds emitted from trees, tend to increase at higher temperatures. Warmer temperatures can also influence—and typically increase—emissions from human sources, especially where electricity generation involves fossil fuel combustion rather than hydroelectric or nuclear sources for power generation. This phenomenon occurs largely through changes in individual behaviours such as increased use of air conditioning in summer months.

In Canada there are broad seasonal variations in air pollution and its health impacts, linked to increased formation of ground-level ozone (which, together with particulate matter (PM), comprises smog) during the summer months. High levels of ozone occur in many areas of Canada, particularly the Windsor-Quebec corridor, the Lower Fraser Valley and parts of the Maritimes, with local episodes experienced in some other areas. The main health effects of ozone include acute and chronic damage to the respiratory system, as well as negative impacts on the cardiovascular system. In 2005, Health Canada estimated that air pollution causes 5,900 premature deaths in eight Canadian cities each year.

Climate influences on air quality also arise through wild fires and forest fires, which occur more frequently in warmer, dryer conditions, and can significantly degrade air quality both locally and far from the location of the fire. For those directly exposed to the wild fires, ash and smoke can cause eye irritation as well as respiratory irritation leading to bronchitis. Wild fires can overwhelm communities through evacuations, dislocation and the loss of homes and other property.

An important concern is the possibility of increased health effects on Canadians through combined exposures to extreme heat and air pollution. However, studies to date show independent effects on health from these hazards, particularly for the most vulnerable populations such as seniors, children and infants, people with chronic diseases and people of lower socio-economic status. While a possible synergistic effect is suspected, scientific evidence through epidemiological studies remains sparse. This is a priority area for future scientific investigation since the combined exposure of Canadians to both hazards is expected to increase in the future.

Current activities to protect citizens from the impacts of extreme heat events and air pollution centre on efforts to alert health authorities and the public when hazardous conditions arise and provide advice on how health risks can be minimized. A number of communities in Canada regularly provide information to the public on the dangers of heat stress and smog episodes to encourage people to take actions to protect their health. For example, the new Air Quality Health Index (AQHI) is a personal health protection tool to be used on a daily basis to make informed decisions about reducing exposure to air pollution and associated health risks. It is accompanied by health advice tailored for vulnerable groups—children and infants, seniors, and people with cardiovascular and respiratory disease and is useful, as well, to guide the activities of the general population.

Wild fires in the British Columbia interior

During 2003, the driest spring and summer since 1929 occurred in the southern interior region of British Columbia. That summer, over 266,000 hectares of forests were swept by wild fires. They cost the lives of three pilots engaged in fire fighting, forced the evacuation of 45,000 people, destroyed at least 350 homes and businesses, damaged infrastructure and required the deployment of 6,000 firefighters. Some of the worst effects on community health and well-being were caused by the Okanagan Mountain Park fire near Kelowna. Increased levels of particulate matter air pollution resulting from the fires led to an increase in respiratory complaints from Kelowna residents, as well as strain on health services. The evacuation and care of hospital patients and residents of chronic care facilities demanded significant effort by health authorities, as well as ambulance services managers and staff, some of whom had also lost their homes to the fire.

Future risks to human health

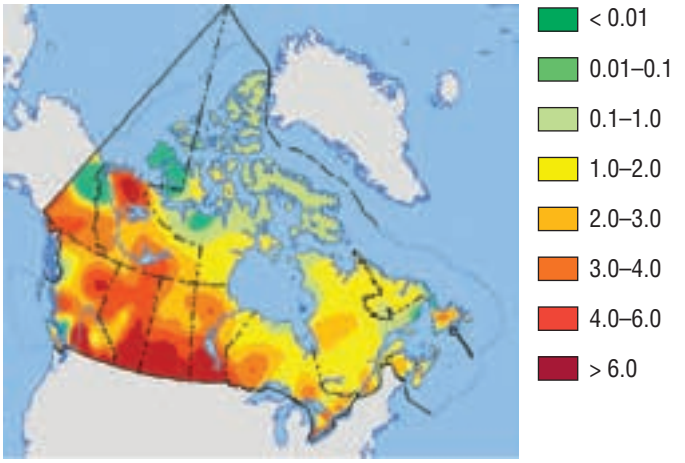
The severity and duration of air pollution episodes are projected to increase in some areas of Canada as a result of a warmer climate. This Assessment estimated changes in air pollution that would occur if there was a 4°C increase in average temperature (from 2002 levels), with anthropogenic emissions kept constant but biogenic emissions increasing in response to the higher temperature. The projected increases in ozone concentrations included an increase in the average daily 8-hour maximum ozone concentration of over 14 parts per billion (ppb) in some parts of the country. The highest increases in ozone levels would occur in Montreal, Toronto, Vancouver, Calgary, Edmonton and Winnipeg. A large increase was also projected for the vicinity of Fort McMurray, in Alberta. The largest increase in the number of days exceeding the Canada-wide Standard for ozone (which is set at 65 ppb) was projected for the Windsor-Quebec corridor, with areas near Vancouver and in Alberta also seeing a significant rise.

The projections also show a decrease in $PM_{2.5}$ at higher temperatures, which results in some accompanying health benefits. This result may be explained by alteration of the chemistry of some components of $PM_{2.5}$ and of their volatility. Specifically, reductions in particulate nitrate concentrations drove the observed reduction in this particular simulation. Even with the reductions in $PM_{2.5}$, however, projections show an overall increase of 312 premature deaths over the modelled summer due to the increases in ozone. Increases in a number of non-mortality negative health endpoints were also projected. It is estimated that these results correspond to a 4.6% ($1.366 billion) increase in the health burden to Canadian society related to air pollution, over the modelled 3-month summer period.

Photo credits: British Columbia Ministry of Forests and Range

Wildfires in British Columbia, 2003

Figure SR–7: Projected forest fire severity levels, 2050 to 2059



Note: the Seasonal Severity Rating, which is a measure of fire danger conditions over a complete fire season, has a relative scale with values above 6 being extreme.

Source: Atlas of Canada, 2007.

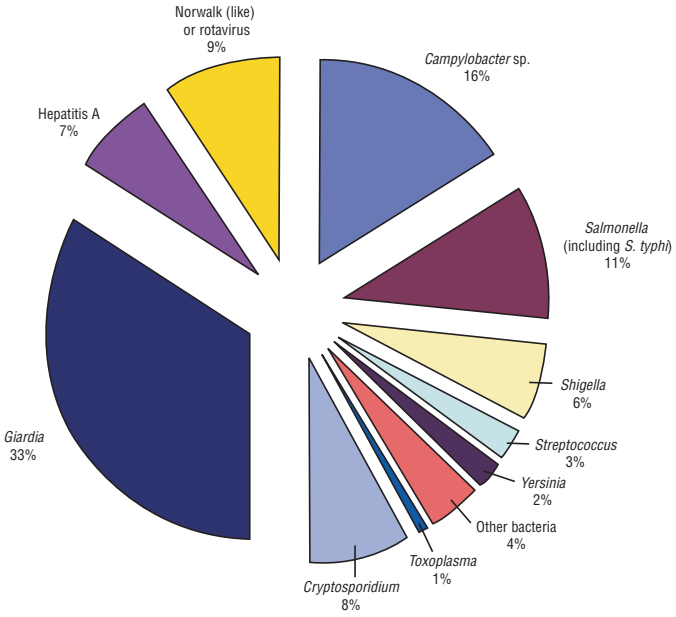
There are other concerns related to air quality, which are also likely to increase as the climate changes. Warmer summers, changes in precipitation patterns and longer growing seasons are expected to increase the types and amounts of airborne allergens in some areas, negatively affecting individuals who are subject to seasonal allergies. In addition, forest fires are projected to increase in most regions of Canada under conditions of higher temperatures (Figure SR–7) and drought, and may produce vast areas of smoke that are transported far from the location of the fire, sometimes hovering over populous areas for long periods of time and impacting health.

Diseases transmitted by water, food, insects, ticks and rodents

Canadians are routinely exposed to infectious diseases that are sensitive to climate variables, such as temperature and precipitation. This includes diseases that are transmitted by insects, ticks, and rodents, as well as through water and food. Some can be transmitted through both food and water, as is the case with some gastroenteric pathogens like *E. coli*. The most common food-borne pathogens in Canada are *Salmonella*, *Campylobacter* and *E. coli*. Gastroenteric pathogens, such as *Giardia*, *Cryptosporidium*, *Campylobacter*, *Shigella*, and *E. coli*, are by far the most common water-borne disease hazards in Canada, while other diseases such as *Salmonella*, toxoplasmosis, hepatitis

and Noroviruses can also be transmitted through water (Figure SR–8). The prevalence of these diseases in humans is mediated by a range of factors including individual behaviours, health protection measures, diagnosis and treatments. Many of these infections can be prevented through targeted health promotion messages that encourage people to take actions to reduce the health risks.

Figure SR-8: Types of pathogens identified in outbreaks in Canada from 1974 to 2001 (n = 150) (other bacteria include *Aeromonas hydrophilia, Bacillus cereus, Enterobacter hafniae*, pathogenic *E. coli, Pseudomonas* spp., *Staphylococcus aureus*)



Several studies have shown that climate variables such as temperature and precipitation can influence the ecology of pathogens (organisms that cause disease) by influencing the pathogens themselves, and by changes in the survival, ability to overwinter and replication rate of vectors. Changing climate conditions can influence transmission mechanisms between vectors and hosts by increasing the time spent outdoors by people in warm conditions and the tendency of ticks to seek out humans. In Canada, some mosquitoes and ticks are vectors for diseases such as West Nile virus, Lyme disease, St. Louis encephalitis, western equine encephalitis and eastern equine encephalitis. Over 1,800 cases of West Nile virus were reported in Canada between 2002 and 2005, with 46 of those resulting in death.

Rodents are the main reservoirs of tick-borne zoonoses (infections that occur in animals and that can be transmitted to humans). They are also hosts of diseases that are transmitted to humans, either by fleas, or without the mediation of an insect vector. Warmer winters and increased rainfall increase rodent survival, and can amplify the abundance of rodent reservoirs of disease. Extreme weather events can increase the likelihood of humans coming into contact with rodents, their fleas and their potentially infective faeces and urine. Rodent-borne diseases such as hantavirus, leptospirosis, bartonellosis and plague are likely common within many rodent populations in Canada. Thirty-six human cases of Hantavirus were reported in Canada between 1989 and 2001.

The climate is also known to influence human behaviours and activities, which can increase the risk of infections. For example, warmer temperatures may result in people spending more time participating in outdoor activities such as camping, swimming and hiking. Food preparation and storage during camping, picnics and barbeques pose greater health risks in warmer temperatures, if appropriate precautions are not taken.

In addition, extreme weather events and climate conditions have played a part in water contamination incidents in Canada. The most common climate-related cause of water contamination in Canada is storm water run-off that flushes contaminants into streams, rivers and lakes, and can transport contaminants into groundwater. Drought can also decrease water levels, which can concentrate pathogens and chemical and radiological contaminants in water, and has implications for hygiene practices in light of water use restrictions.

Federal, provincial and municipal health officials collaborate to protect citizens from many infectious disease risks by carrying out surveillance, undertaking needed preventative interventions and through the diagnosis and treatment of infected and infectious individuals. For example, the National Notifiable Diseases On-Line registry, and the Canadian Communicable Disease Report provide timely information on case reports and surveillance results of infectious diseases of concern to Canadians.

Future risks to human health

Climate change is likely to affect the patterns of some infectious diseases across the country, and may result in the emergence of diseases that are currently thought to be rare in or exotic to Canada. The increased temperatures associated with climate change could increase the survival or replication rates of disease vectors and some pathogens that can be found in food or water. Longer summers will extend the period associated with higher-risk behaviours and hotter temperatures may contribute to a higher incidence of disease. More frequent and intense rainfall events and more frequent drought, which are projected for many Canadian communities, may increase risks of water contamination and water-borne disease outbreaks. The importance of educating the public about safe food preparation and handling practices, and threats to drinking and recreational waters, through regular advisories, will increase in the future as the climate continues to change.

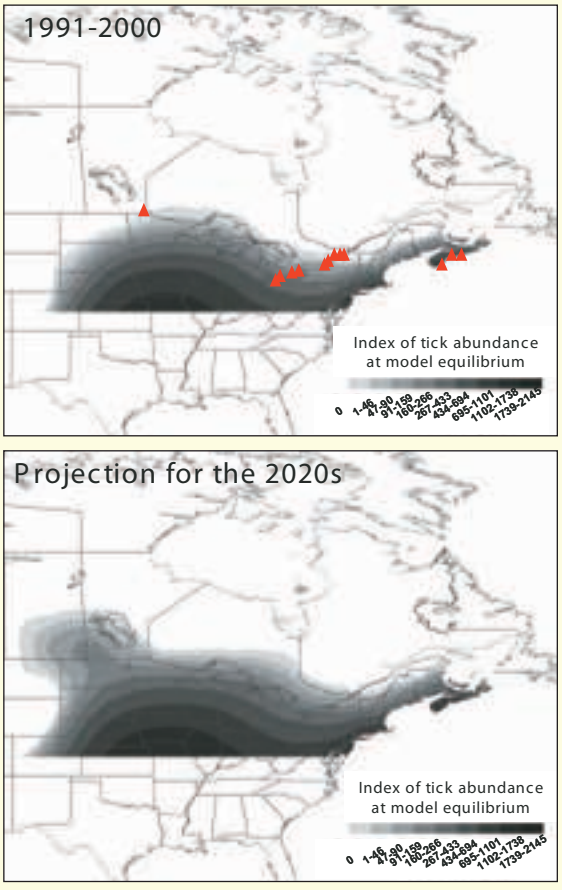
Milder winters followed by prolonged summer droughts and heat waves could favour the spread of West Nile virus and Lyme disease through changes in mosquito and tick populations. In regions of Canada where low temperatures, low rainfall, or the absence of vector habitat have restricted the transmission of vector-borne diseases, climate change could tip the ecological balance and trigger outbreaks of diseases previously rare or unknown in Canada. Climate change-related alterations in the worldwide distribution and transmission intensity of various vector-borne diseases could also increase the exposure of Canadian travellers to these diseases. For example, travel between Canada and newly-endemic malaria regions could potentially increase the importation of malaria cases into Canada.

Health and emergency sector decision makers require information about population and regional vulnerabilities associated with weather-related natural hazards, air pollution, and diseases transmitted by water, food, vectors (insects and ticks) and rodents and how they will increase due to climate change. It is clear that some risks are more immediate than others and that threats to health posed by climate change differ signficantly by region. Many risks can be prevented or reduced with the implementation of known protective behaviours by individual Canadians. Others will require improvements to critical infrastructures, public health capacity, urban planning and design, and emergency management systems.

Possible spread of Lyme disease in Canada

Lyme disease is a bacterial infection that causes a skin rash, chronic arthritis, nervous system disorders and debilitation. It is caused by a bacterium transmitted by ticks when they attach to the skin in order to feed. The black-legged or deer tick (*Ixodes scapularis*) is the most common vector in eastern North America, except in British Columbia where a related tick (*I. pacificus*) is the vector. Climate change may alter the risk of Lyme disease in Canada. Higher temperatures will shorten tick life cycles, create more favourable conditions for host-seeking activity and increase tick survival. This is likely to increase the probability that new tick populations will become established in Canada, leading to the creation of new endemic areas of Lyme disease. The red triangles represent observed tick populations (Figure SR–9).

Figure SR–9: Possible spread of *I. Scapularis* in Canada under climate change



Source: Ogden et al., 2006.

NORTHERN CANADIANS AND THEIR COMMUNITIES FACE DISTINCT CHALLENGES

The effects of the changing climate are most visible in Canada's North. This vast region of Canada encompasses diverse ecosystems, climate systems and cultures. According to both scientific measurements and local knowledge, decreases in the extent and thickness of sea ice in Arctic waters, melting of permafrost, coastal erosion and changes in the distribution and migratory behaviour of certain wildlife species have been observed and recorded.

Approximately 150,000 people live in Canada's North, one half of which live predominantly in small and often isolated communities. These communities—with their close relationships to unique and highly variable local environments—are the most vulnerable to climate change. The observed changes are already having an impact on health and safety (Table SR–4). Increasing ice instability is making travel more dangerous. In the Northwest Territories land and sea-based accidents appear to be increasing. Young male Aboriginals[4] are particularly vulnerable to these hazards because of less frequent participation in land and sea-based activities and therefore less experience with environmental hazards than previous generations. In some areas of the North changes in temperature and precipitation patterns have increased risks from avalanches, landslides and other hazards. Communities located in some mountainous regions, including areas of the Yukon, and eastern communities of Baffin Island, Nunavik and Labrador, are vulnerable to avalanche and landslide events.

Food security is also of concern to all northern communities. Climate change and variability are influencing the distribution, availability and accessibility of wildlife that contributes to the diet of most Northerners. In addition, the ability to safely store food has been compromised in some communities due to rising temperatures and loss of permafrost. This is a concern because the social and cultural values associated with the acquisition, preparation, sharing and consumption of traditional/country foods continue to be an important aspect of health and well-being, particularly for Aboriginal Northerners.

Photo credits: Peter Langer

Communities and households are being affected by impacts related to water availability and water-borne infections. Many traditional sources of water are disappearing or becoming contaminated. Some communities with water treatment have found that their systems are being stretched to, or beyond, the limits of safety because of warmer temperatures or other climate-related changes in the environment. Household water storage systems are also vulnerable to higher temperatures. Improvements to surveillance activities will allow for identification of the most vulnerable communities.

Many factors combine with climate change to increase the vulnerability of people living in small northern communities to health impacts. These include existing health disparities, limited access to public health and emergency management services, a lack of nutritious food sources, inadequate infrastructure and poor housing conditions. Across the North, the deterioration of cultural ties to local environments is one of the most serious threats to health and well-being among Aboriginal people and, in many communities, this is being exacerbated by the impacts of climate change.

4 In this document, "Aboriginal" refers collectively to those individuals recognized as "First Nations," "Inuit" or "Métis" in Canada.

Table SR-4: Climate change impacts and exposure to related health risks in the North

	Climate change impacts	Potential health risks
Direct Impacts	Extreme precipitation events and natural hazards	• Increased risk of landslide and avalanche-related injuries and mortality
	Unpredictability of weather conditions	• Increased frequency and severity of accidents resulting in injury or death while hunting and travelling
	Temperature-related injuries	• New danger of heat-related health risks, including respiratory effects • Possible decrease in cold-related injuries and deaths, may be off-set by increased unpredictability
	Changing ice and snow conditions	• Increased frequency of accidents causing injury or death while on ice • Decreased access to traditional/country food items • Challenges to building shelters (igloos) for safety while on the land
Indirect Impacts	Changes in air pollution (contaminants, pollens and spores)	• Increased incidence of respiratory and cardiovascular diseases • Increased exposure to environmental contaminants
	Increased exposure to UV radiation	• Increased incidence of rashes, sunburn, and snow blindness
	New and emerging diseases	• Increase in infectious disease incidence and transmission • Increased exposure to existing and new vector-borne diseases
	Food security	• Decreased access to traditional/country food items • Decreased food security • Erosion of values associated with the preparation, sharing and consumption of traditional/country foods
	Water security	• Reduced access to potable water on the land • Increased incidence of diarrheal and other infectious diseases
	Permafrost instability	• Negative impacts to stability of public health, housing and transportation infrastructure
	Sea level rise and coastal erosion	• Psychosocial disruption associated with infrastructure damage and community relocation

Despite these vulnerabilities, northern households and communities continue to demonstrate a capacity to adapt relying on existing cultural and societal ties and a traditional subsistence economy. Adaptation is occurring in many forms. Residents across the North are promoting measures to minimize risks such as a return to the use of dog teams because of their greater innate navigation abilities in storms. Hunters are using huts and cabins more frequently for protection from extreme and unpredictable weather and bringing more supplies on hunting trips, including, in some regions, drinking water. Technological solutions, such as the use of geographic positioning systems (GPS) have also been adopted to reduce travel risks. Some Northerners have installed screens on windows in their homes as a response to increased heat and insect populations. At the community level, adaptation measures have been adopted such as changes to the timing of hunting seasons, ice safety monitoring programs, increased screening of wild meats for parasites and other diseases, and community freezer programs. Some coastal communities are taking actions to reinforce their shorelines and vulnerable infrastructure, sometimes relocating structures to safer areas.

The effects of continued warming and changes in precipitation across the North need to be better understood as well as how exposure to climate-related health risks and

adaptive capacity vary throughout this region. Research is needed to identify the most vulnerable populations and communities through a better understanding of the interactions between the environmental, social, economic and cultural changes taking place in the North. Current practices and new adaptations need to be evaluated in order to promote widespread adoption. Concerted efforts are required to bring together the resources and knowledge necessary to improve health surveillance and monitoring, public health infrastructure and health promotion programs that will reduce the health risks associated with climate change.

CANADIAN CAPACITY, VULNERABILITY AND BARRIERS TO ADAPTATION

Understanding vulnerabilities to the health impacts of climate change requires an understanding of the interaction among three variables: the *exposure* of individuals or populations to climate hazards, *sensitivity* to the impacts, and the *adaptive capacity* of individuals, populations and communities. Adaptive capacity is also known as the ability to cope with the consequences of an event, or the ability of a system to manage change. At the national and community level it is influenced by access to technologies, economic resources, information and skills, the current state of infrastructure, institutional arrangements, social networks, and population health status.

The ability of Canadians to cope and adapt to future conditions will determine how much climate change will affect health. The adaptive capacity of individuals is strongly influenced by a broad range of determinants of health, such as personal health status and coping skills, education and socio-economic status, social networks, and access to resources. Overall, Canadians enjoy very good health status and a high level of health and social services, providing a strong foundation for coping with the diverse stresses that climate change will place on health and well-being. However, people in poor health, precarious living conditions, and with limited economic means generally have more difficulty coping with environmental stresses.

The Assessment inventoried a range of measures and factors that contribute to the ability of governments and communities to adapt to current climate-related health risks and highlighted areas where gaps have been reported in previous studies and audits, or by experts. Significant barriers to adaptation exist such as an incomplete knowledge of health risks, uneven access to protective measures, limited awareness of best adaptation practices to protect health and constraints on the ability of decision makers to strengthen existing health protection programs or implement new ones. In order to effectively reduce current and future risks, a better understanding of the motivations and abilities of individual Canadians and public health and emergency management decision makers is necessary.

Vulnerability to climate-related health risks today

The health of every Canadian can be affected by weather-related hazards, diseases transmitted by water, food, insects, ticks, or rodents, extreme heat and air pollution—all of which are expected to be exacerbated by climate change. Vulnerabilities within a population are uneven. Some individuals or groups may be more sensitive or more exposed to climate hazards, while others may have a greater capacity to cope. Understanding of the factors that create particular vulnerabilities to certain risks has increased which allows identification of characteristics within the Canadian population that should guide decisions regarding where, when and for whom adaptations are needed. Identifying these different sensitivities and variations in exposure to climate hazards is an essential step to developing effective interventions and adaptations to protect those most at risk.

Canadians most vulnerable to climate change health impacts

- *Seniors* who take certain medications, have chronic health problems, live alone, or have impaired cognition or reduced mobility, are more vulnerable to health risks associated with a number of climate-related hazards, such as extreme weather events. Seniors face physiological limitations in their ability to cope with certain temperatures or events.
- *Children and infants* are especially vulnerable because they are unable to protect themselves and must rely on the assistance of a caregiver to protect them from hazards. Their physical characteristics and behaviours—relatively high intake of water, air and certain foods, hand-to-mouth behaviour, rapid growth and development, immature physiology and metabolism—also increase their vulnerability to climate-related hazards.
- *Socially disadvantaged individuals* may find it more difficult to cope with the effects of hazards as they may already experience chronic stress or other health conditions and have limited financial means.
- *People with pre-existing illnesses* including chronic diseases such as cardiovascular disease, neurological and mental illness, diabetes, asthma and other respiratory diseases and cancer can exhibit increased sensitivity to the health impacts of climate change. People who are ill may be more sensitive to vector-borne infectious diseases, water- and food-borne contamination, and smog and heat events.

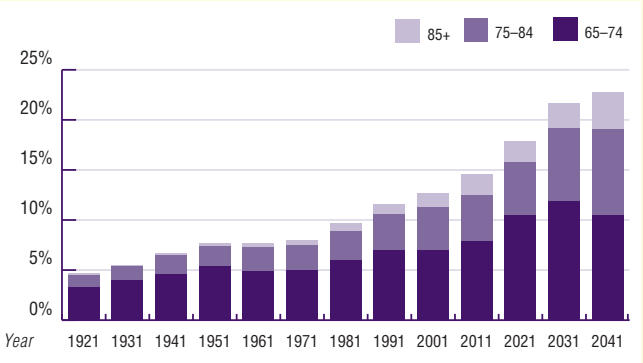
Vulnerability trends for Canada's future

Many Canadians are highly sensitive to the health impacts of climate change. As Canada's population grows and as climate change expands the geographical range, frequency and intensity of many existing climate-related hazards, the exposure of individuals to extreme weather events, diseases transmitted by water, food, insects, ticks, or rodents, extreme heat and air pollution will increase. In addition, expected population growth and chronic disease trends indicate that the proportion of Canadians highly sensitive to climate-related health impacts will grow over the coming decades, although this may vary by region and could be influenced by other factors such as access to health care and community support services. The number of Canadian seniors is growing dramatically and this population cohort is expected to almost double in size by 2031 (Figure SR–10). By then, one in four Canadians will be over the age of 65. The number of individuals suffering from chronic illnesses, such as heart disease, cancer and respiratory diseases, is also on the rise.

Climate change has already started to affect the environment, the economy, and infrastructure that play important roles in the health status of Canadians. The scope of these changes is reported in the Government of Canada report *From Impacts to Adaptation: Canada in a Changing Climate 2007*. Successfully preparing for climate change health risks requires consideration of possible cumulative health effects of multiple events and the interaction between several factors which may stress health and emergency management systems and enhance vulnerabilities. This is difficult because of limited understanding of the interactions among events that can impact upon health as well as the methodologies and data for such complex analyses.

Gaps have been reported in measures and systems in Canada that aim to reduce climate-related health risks. Parliamentary reviews and other reports have raised concerns about emergency management systems calling for renewed government leadership, improved funding arrangements, and enhanced coordination and information-sharing initiatives. The age of infrastructure integral to the protection of human health—such as roads, sewage treatment, storm sewers, and water distribution networks—also contributes to the vulnerability of citizens to a range of climate-related hazards, but its renewal presents

Figure SR–10: Seniors by age sub-groups, as % of total population, Canada, 1921–2041



Source: Government of Canada, 2002.

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 and over) is also likely to increase sharply; in 2005 one in 30 Canadians was 80 or over, by 2056 it will likely be one in 10.

opportunities to effectively reduce future risks. The ability to respond to disease outbreaks and public health emergencies in Canada is highly influenced by funding for a number of public health functions, the ability to exchange and share surveillance and monitoring data, and human resource planning and training. Current efforts to protect Canadians from health risks associated with extreme heat events are hampered by limited knowledge of effective heat alert and response systems for different types of communities in Canada. In addition, measures designed to mitigate the urban heat island effect (generated by asphalt surfaces and other materials that absorb heat) are limited in Canadian communities.

Adaptive capacity is also not evenly distributed among communities in Canada. Urban residents are highly vulnerable to the health impacts of natural hazards because of higher population densities and a reliance on technologies and complex infrastructures. Many of Canada's major cities also experience hotter temperatures during heat waves than surrounding suburban and rural areas due to the urban heat island effect. However, they may also have greater adaptive capacity stemming from more extensive emergency, health and social services, and economic resources necessary to respond to extreme weather events and recover from disasters. In contrast, small communities often do not have the capacity to cope with extreme events or health emergencies as they have fewer resources available and offer a more limited array of public services. These communities are also less likely to have undertaken assessments of climate change risks or developed adaptation measures, while their location may often put them more at risk from extreme weather events to begin with. Canadians must be prepared to deploy existing knowledge and resources to ensure that capacity is broadly distributed across society and that no region or part of the population is left unprepared. Rural communities and those in Canada's North face unique challenges, and while many urban areas are becoming sophisticated in public health programming, the number and complexity of issues they face is increasing which is challenging their ability to adapt to climate change.

From a public health perspective, the key systems that must have the adaptive capacity necessary to cope with anticipated climate change impacts are emergency management systems, critical infrastructure, and public health systems and institutions. The capacity of current facilities, including community health centres, hospitals, shelters, and long-term care residences, will be tested as the health of Canadians is impacted from increased climate variability and change. The projected increase in Canada's population—in particular an increase in the size of the seniors' cohort—will contribute to the pressures on facilities and health care professionals, especially if Canada experiences the projected increase in the number and severity of extreme weather events. Health and social services can quickly become overwhelmed in such events resulting in significant impacts on human health.

From national to local levels, recent initiatives—such as the creation of the Public Health Agency of Canada, the National Framework for Health Emergency Management, the National Disaster Mitigation Strategy, the Building Canada Infrastructure Program, the launch of the Air Quality Health Index, and Quebec's Climate Change Action Plan—have improved the ability of governments and communities to mitigate, prepare for and respond to public health emergencies and other climate-related health risks. Investments have been made at all levels to improve capacity, and partnerships among governments and non-governmental organizations are improving coordination, collaboration and information sharing to provide more effective management of a variety of health risks. However, climate change is expected to increase a broad range of risks to the health of Canadians. Without further adaptation strategies, the impacts on health could also increase along with pressures and costs on existing health and social services.

Storm surge simulations in Atlantic Canada

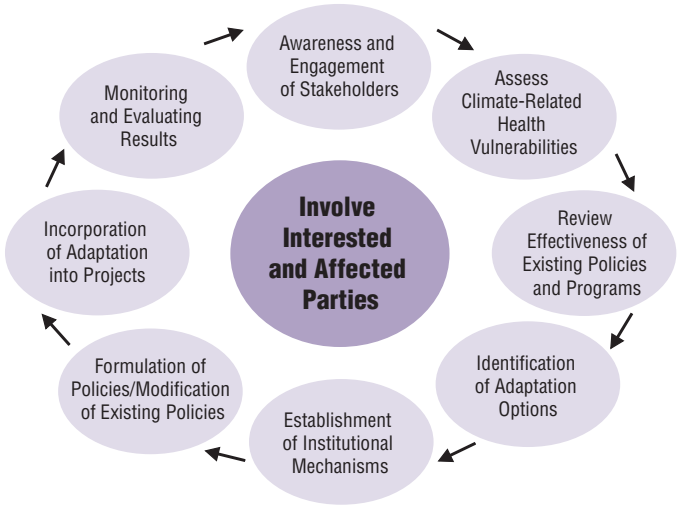
In 2005, coastal communities in Atlantic Canada—Shediac/Cap-Pelé, New Brunswick, and Channel-Port aux Basques, Newfoundland and Labrador—tested their emergency response plans to better prepare for storm surges, which are expected to become more frequent and intense due to climate change. Representatives of municipalities, police and fire departments, health centres, hospitals, provincial governments, the federal government and non-profit organizations actively participated in the simulation. The exercises proved to be an effective research method to identify capacity and gaps. They also met training objectives by enabling participants to better understand the potential impacts of such an event, identify the vulnerable geographical areas and populations, identify shortcomings in the emergency management plans and community capacity, and improve future collaboration among stakeholders.

MOVING FORWARD: OPPORTUNITIES FOR REDUCING VULNERABILITY TO CLIMATE CHANGE HEALTH IMPACTS

Adaptation can reduce health risks posed by climate change by providing individuals with the knowledge, tools and confidence needed to take protective actions. *Human Health in a Changing Climate* increases understanding of how climate-related risks to health are currently managed, how they are expected to change in the future, what makes some people more vulnerable, and the types of actions that can be effective in reducing risks. Some actions are already being taken to address health risks associated with climate variability and change, but challenges lie ahead. Efforts are needed to address gaps in existing knowledge of the risks and of vulnerable populations, build adaptive capacity and develop effective solutions that will take into consideration future climate conditions so that harm to Canadians can be minimized. Moving forward with needed adaptations to reduce health risks associated with climate change can bring important near- and long-term "co-benefits" to communities. For example, less traffic congestion, improved physical fitness and better quality of life can result from improvements in active transportation infrastructure, which are aimed at adapting to future heat waves by reducing the urban heat island effect.

Canadians have the advantage of many years of experience in coping with climate variability and extreme weather. Knowledge about the processes of adaptation from the fields of risk management, natural hazards research, and resource development and planning is available to inform adaptation planning and vulnerability reduction in Canadian communities. The process of developing an adaptation strategy to reduce climate-related health risks should involve all interested stakeholders and officials within and outside of the health sector (Figure SR–11). Many years of experience in reducing risks to health from environmental hazards and a high level of awareness among public health officials in Canada about potential impacts provide opportunities to move forward with the development of neeeded adaptations.

Figure SR–11: Process for Adaptation Development and Implementation in the Health Sector



Source: Adapted from Penney and Wieditz, 2007.

The ability of all Canadians and their communities to plan for and respond effectively to climate change should be increased through actions in the following areas:

The health sector needs to maintain current efforts to protect health from climate-related risks, and incorporate climate change information and engage other sectors in their plans for future programs

Public health officials in Canada recognize that weather and climate have an impact on human health and well-being, and recent research suggests that most feel climate change will increase risks to health. However, climate change has not been a priority for most health planners and program managers because of inadequate knowledge about existing vulnerabilities in their respective communities and due to resource constraints. The health sector can proactively address health risks associated with climate change through enhanced vulnerability assessment activities and disease surveillance. Health sector officials also have a strong interest in working closely with those in other sectors and promoting the need to collaboratively prepare for the impacts of climate change. Reducing risks to health ultimately requires effective adaptations by a range of sectors that experience impacts such as transportation, tourism, recreation, fisheries, forestry, agriculture, industry and energy.

The convergence of increased workloads and more frequent emergencies from natural hazards related to climate change may reduce the ability of the health system to protect individuals and their families. Planning for the impacts of climate change through the development of the needed capacity to address future health risks is essential for protecting the health of citizens.

Regional and community-level assessments of health vulnerabilities are needed to support adaptation through preventative risk reduction

Assessments provide the information needed to identify public health and emergency management activities that should be augmented at the local level to reduce risks to health. As climate change impacts on Canadians will vary from location to location, communities and regions need to conduct their own investigations of existing vulnerabilities. This information will help identify the areas where enhanced capacity is needed to protect populations, and the adaptive strategies which should be implemented immediately to reduce risks. These assessments should focus on socio-economic and climate conditions, and identify areas where human health is currently being impacted by climate, and may be impacted in the future, so that adaptations and strategies can be developed to address gaps.

Multi-disciplinary research and collaborations across all levels of government can build the knowledge base on vulnerabilities to climate change to address existing adaptation gaps

It is essential that emerging information about health risks and vulnerabilities is made available to decision makers in the health and related sectors to develop needed adaptation strategies. Research to improve knowledge in the following areas would significantly benefit future assessments at the national and regional levels as well as current efforts to manage climate-related health risks.

- Improved *climate models and scenarios*, particularly at the regional scale, to reduce uncertainty about future risks, exposures and hazards for vulnerable populations;
- Characteristics and qualities that make specific *vulnerable populations* more susceptible to health impacts and, conversely, factors that can influence an individual's capacity to adapt; and
- Identification and evaluation of cost-effective *adaptation strategies and measures* to protect human health—this includes cost-benefit analyses, identifying best-practices, evaluating new infrastructure designs, investigating the uptake of adaptation in decision making and other factors that contribute to building capacity, and improving surveillance and monitoring.

Climate change adaptation in Quebec

One element of the assessment of health impact on Quebeckers (Chapter 6) included identification of current adaptation measures in place, perceptions of risk among the public and decision makers, and future options for protecting health. At the individual level, people living in Quebec are taking a number of actions to reduce risks to their health from heat waves and cold snaps. However, there is room for improvements related to education about the wind chill index in the winter, assistance for people with mobility impairment during extreme heat or cold temperatures and energy efficiency upgrades to older apartments.

At the institutional level, a number of adaptations are currently under way. Numerous cities in Quebec have developed heat wave warning systems, together with public education tools to raise awareness of the risks from extreme heat. Other actions being considered include increasing the number of trees in cities, utilizing green roof technologies and reducing car use through increased use of public transportation, all of which help to alleviate the urban heat island effect.

Adaptation to extreme weather events in Quebec is also well developed, based in large part on responses to the Saguenay flood of 1996 and the 1998 ice storm. A storm and flood detection system and real-time surveillance of dams and rivers are in place for the entire province, and a new, standardized approach to risk analysis and management is being implemented for municipalities. In addition, legislative reform with a view to better control of vector-borne and zoonotic diseases has led to significant investment in monitoring and laboratory testing in the agricultural sector.

Municipal and public health managers in Quebec currently perceive vulnerabilities in their regions (e.g. environmental, socio-economic, health-related), report current impacts from climate change and identify the need to implement climate change adaptation programs. Most municipal and health managers were concerned with the regional and provincial impacts of climate change over a period of 10 years and almost all other respondents over a period of 20 years. Similarly, most managers identified the need, over the next 10 years, to implement climate change intervention programs. Surveys also found that the public also tended to agree on the need to take action to reduce the harmful effects of climate change.

Photo credits: Canada Centre for Remote Sensing, NRCan

The Ouranos Consortium in Quebec, which brings together contributions from various government departments and 150 academic and institutional researchers, is providing valuable momentum to research on impacts and adaptation issues in that province. A three-year health research project was adopted by the group (Table SR–5) and it contributes to the implementation of the Quebec Climate Change Action Plan 2006–12 which addresses priority needs, including risks to health.

Table SR–5: Projects under the Ouranos health program, 2006–09

Theme	Title
Heat Waves and Climate Warming	1. Additional historical analyses of hospital morbidity, emergency room visits and general mortality as a function of historic temperatures and simulated analyses for the 2020, 2050 and 2080 horizons. 2. Implementation of roundtables to assess the measures required for adaptation to climate change: institutional and clinical components. 3. Identification of sectors vulnerable to intense heat in a Canadian metropolis for intervention and research on public health.
Other Extreme Climate Events	4. Feasibility study for the development of real- and non-real time tools for surveillance of the health effects of extreme climate events.
Air Quality	5. Estimation of future smog levels with the Unified Regional Air-quality Modelling System (AURAMS) and the Canadian Regional Climate Model (CRCM). 6. Fine spatial variations in mortality and hospitalization with extreme climate events in urban environments.
Water Quality	7. Feasibility study of water management projects using current Ouranos water projects. 8. Incidence and distribution of gastrointestinal illnesses among populations at risk and the risk factors associated with climate and agricultural practices.
Integration, Communication and Strategic Support	9. Development of an interactive atlas on health vulnerabilities associated with climatic change. 10. Integration, dissemination and transfer of knowledge and support for Ouranos activities by the Quebec MSSS and its networks, Health Canada and the World Health Organization.

By choosing to pursue the path of adaptation, Canadians will have the opportunity to address existing disparities in capacity among individuals and communities through the sharing of information, technologies and resources. Many actions to reduce health risks from climate change will entail revising, reorienting or strengthening current public health policies and practices to ensure that there is an adequate focus on vulnerable populations. A number of the actions that are being taken now to protect citizens from health risks associated with air and water pollution, infectious diseases and severe weather events provide the basis for a first response in planning for climate change.

Protecting Canadians from extreme heat

The number of +30°C days and the frequency and intensity of heat waves is projected to increase as warming continues. Several Canadian cities and municipalities have implemented heat warning systems and developed interventions to protect vulnerable populations from health risks associated with extreme heat. Canada can build on the success of current adaptations by increasing the number of communities taking actions to protect vulnerable populations from health risks associated with heat waves, and by expanding the number of large urban centres taking preventative measures to mitigate impacts by reducing the urban heat island effect. These efforts should be supported by research on the most effective ways to change individual behaviours, and through the development of guidance and best-practices to improve the effectiveness of existing heat alert systems and support the creation of new ones.

There are abundant opportunities in Canada to "mainstream" adaptation in new programs and policies. The concept of mainstreaming climate risks describes processes that bring explicit consideration of climate and related risks into current decision making processes and everyday practices. For example, the development of infectious disease monitoring and surveillance systems can utilize information about how ecological changes from a changing climate may alter disease risks in the population. In addition, smart land-use plans and development are critical for preventing loss of life, injuries and property from extreme weather events. New construction and urban plans and design should incorporate adequate resistance to natural hazards, such as heat waves or flooding, which are projected to increase in intensity as the climate continues to change.

Improved knowledge about the nature of climate-related hazards and their impacts on health facilitates the development of effective risk management strategies, which can be incorporated, or mainstreamed, into a range of professional practices in emergency management, infrastructure development, clinical care and public health fields.

Canada now has an opportunity to proactively plan for, and reduce, adverse health outcomes related to climate change, while addressing key stressors on human health that are already affecting individuals and communities. Our ability to make progress depends on the willingness and determination of Canadians and their institutions to adapt to the short- and long-term changes, and to fully utilize existing capacity to manage health risks. All levels of government need to work together—and with interested parties such as professional associations, community leaders, businesses, voluntary sector organizations and public health practitioners—to address the impacts of climate change on health. Future partnerships will benefit from growing knowledge about health risks related to climate change that Canadians face, and the sharing of adaptation experiences across jurisdictions and among public health and emergency management officials in Canada and elsewhere in the world.

REFERENCES

Atlas of Canada. (2003). *National annual precipitation scenario: 2050*. Retrieved January 9, 2008, from http://atlas.nrcan.gc.ca/site/english/maps/climatechange/scenarios/nationalannualprecip2050

Atlas of Canada. (2007). *Projected forest fire severity level, 2050 to 2059*. Retrieved March 10, 2007, from http://atlas.nrcan.gc.ca/site/english/maps/climatechange/potentialimpacts/severityratingsforestfires2050-2059

Canadian Red Cross. (2005). *Expect the unexpected program*. Retrieved April 1, 2005, from http://www.redcross.ca/article.asp?id=009874&tid=028

Confalonieri, U., Menne, B., Akhtar, R., Ebi, K.L., Hauengue, M., et al. (2007). Human health. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (Eds.), *Climate change 2007: Climate change impacts, adaptation and vulnerability. Working Group II contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report* (pp. 391–431). Cambridge, U.K.: Cambridge University Press.

Etkin, D., Haque, E., Bellisario, L., and Burton, I. (2004). *An assessment of natural hazards and disasters in Canada: A report for decision-makers and practitioners.* Ottawa: Public Safety and Emergency Preparedness Canada (PSEPC).

Government of Canada. (2002). *Canada's aging population.* A report prepared by Health Canada in collaboration with the Interdepartmental Committee on Aging and Seniors Issues. Ottawa: Author.

Government of Quebec. (2006). *Quebec and climate change: A challenge for the future. 2006–2012 action plan.* Québec: Author. Retrieved November 21, 2006, from http://www.mddep.gouv.qc.ca/changements/plan_action/2006-2012_en.pdf

Health Canada. (2005). *Your health and a changing climate: Information for health professionals*. Ottawa: Author, Climate Change and Health Office.

Hengeveld, H., Whitewood, B., and Fergusson, A. (2005). *An introduction to climate change: A Canadian perspective.* Ottawa: Environment Canada.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate change 2007: The physical science basis. Working Group I contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, et al. (Eds.). Cambridge, U.K.: Cambridge University Press.

Lemmen, D.S., Warren, F.J., Lacroix, J., and Bush, E. (Eds.). (2008). *From impacts to adaptation: Canada in a changing climate 2007.* Ottawa: Government of Canada.

Ogden, N.H., Maarouf, A., Barker, I.K., Bigras-Poulin, M., Lindsay, L.R., et al. (2006). Climate change and the potential for range expansion of the Lyme disease vector *Ixodes scapularis* in Canada. *International Journal for Parasitology,* 36, 63–70.

Penney, J., and Wieditz, I. (2007). *Cities preparing for climate change: A study of six urban regions*. Prepared by the Clean Air Partnership (CAP) for Natural Resources Canada (NRCan).

World Health Organization (WHO). (2006). *The Constitution of the World Health Organization.* Retrieved January 10, 2008, from http://www.who.int/governance/eb/who_constitution_en.pdf

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