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Human Health in a Changing Climate:

A Canadian Assessment of Vulnerabilities and Adaptive Capacity

Canada

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Edited by:

Jacinthe Séguin
Health Canada

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Également disponible en français sous le titre :
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This publication can be made available on request on diskette, large print, audio-cassette and braille.

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Publications
Health Canada
Ottawa, Ontario K1A 0K9
Tel.: 613-954-5995
Fax: 613-941-5366
E-Mail: info@hc-sc.gc.ca

HC Pub.: 4038
Cat.: H128-1/08-528E
ISBN: 978-0-662-48365-6

Cover photo of Saguenay flood courtesy of the Canada Centre for Remote Sensing, Natural Resources Canada.

EDITOR

Jacinthe Séguin	Health Canada

AUTHORS

Diane Bélanger	Institut national de santé publique du Québec and Centre hospitalier universitaire de Québec
Peter Berry	Health Canada
Véronique Bouchet	Environment Canada
Dominique Charron	International Development Research Centre
Kaila-Lea Clarke	Health Canada
Bernard Doyon	Centre hospitalier universitaire de Québec
Manon Fleury	Public Health Agency of Canada
Christopher Furgal	Indigenous Environmental Studies Program, Trent University
Pierre Gosselin	Institut national de santé publique du Québec, Ouranos and Centre hospitalier universitaire de Québec
Serge Lamy	Health Canada
L. Robbin Lindsay	Public Health Agency of Canada
Gordon McBean	Institute for Catastrophic Loss Reduction and Departments of Geography and Political Science, University of Western Ontario
Nicholas H. Ogden	Public Health Agency of Canada
Jacinthe Séguin	Health Canada
Corinne J. Shuster	United Nations University
Colin L. Soskolne	School of Public Health, University of Alberta

CONTRIBUTORS

Peter Berry (Health Canada), Mark Buell (National Aboriginal Health Organization), Kathleen Buset (Environment Canada), Laurie Chan (University of Northern British Columbia), Quentin Chiotti (Pollution Probe), Kaila-Lea Clarke (Health Canada), Sophie Cousineau (Environment Canada), Victoria Edge (Public Health Agency of Canada), Gylda Fry (Health Canada), Christopher Furgal (Trent University), Mélissa Giguère (Institut national de santé publique du Québec), Andrew Hallak (Institute for Catastrophic Loss Reduction), Michel Jean (Environment Canada), Barry Jessiman (Health Canada), Branka Jovic (Health Canada), Stan Judek (Health Canada), Cheryl Khoury (Health Canada), Justine Klaver-Kibria, Tom Kosatsky (BC Centre for Disease Control), Paul Kovacs (Institute for Catastrophic Loss Reduction), Marie-Andrée Lévesque (Université Laval), Eric Litvak (Direction de santé publique de Montréal), Daniel Martin (Public Health Research Unit, CHUQ-CHUL), David Noble, Nicholas Ogden (Public Health Agency of Canada), Radenko Pavlovic (Environment Canada), Nedka Pentcheva (Environment Canada), Dieter Riedel (Health Canada), Jacinthe Séguin (Health Canada), Dave Stieb (Health Canada), Jinhui Zhao (Institute for Catastrophic Loss Reduction).

ACKNOWLEDGEMENTS

The Climate Change and Health Office at Health Canada gratefully acknowledges the contribution of the following people in providing guidance, reviewing chapters and providing written comments, and assisting in the coordination of activities that made this publication possible:

Steering Committee

Horacio Arruda	Council of Chief Medical Officers of Health
Alain Bourque	Ouranos, Quebec
George de Berdt Romilly	Climate Canada Atlantic, Nova Scotia
Daniel Krewski	Institute for Population Health, University of Ottawa
Robert Lannigan	Department of Microbiology and Immunology, University of Western Ontario
Don Lemmen	Natural Resources Canada
Don MacIver	Environment Canada
Gordon McBean	Institute for Catastrophic Loss Reduction and Departments of Geography and Political Science, University of Western Ontario
Lisa Stringer	Public Health Agency of Canada
John Wellner	Ontario Medical Association

Reviewers

Vic Adamowicz, Terry Battcock, Lianne Bellisario, Jim Berner, Ian Burton, Monica Campbell, André Cyr, Jean-François Dionne, Kristie Ebi, Betty Edwards, David Etkin, Mark Goldberg, Pierre Gosselin, Emdad Haque, Dave Hutton, Roy Kwiatkowski, John Last, Don Lemmen, Diane McClymont-Peace, Véronique Morriset, Linda Mortsch, Simone Powell, Timothy Ramsay, Dieter Riedel, Guy Sanfaçon, Ryan Schwartz, Don Shropshire, Barry Smit, Robert Smith, Paul Socket, Craig Stephen, Douw Steyn, Dean Stinson O'Gorman, Pierre Valois, Lisa Van Buren, Jay Van Oostdam, David Waltner-Toews, Leslie Whitby, and Kue Young.

Secretariat and Peer Review Coordination

Marcia Armstrong, Ben Brisbois, Kaila-Lea Clarke, Jim Frehs, Catherine McIntosh, Dawn Paszkowski, Mark Saigeon, Anita Walker, Catherine Wilde, and Anna Yusa.

PREFACE

Doctors, nurses, and public health and emergency management officials are continually on alert for changes that will affect the well-being of the population. Increasingly they have recognised the impacts that environmental degradation can have on health and are seeking information to support needed clinical interventions and public health programs. Awareness of climate change and of the possible repercussions on health is growing among these health care professionals and decision makers but gaps in the knowledge of existing and future risks remain important barriers to adaptation. Health Canada undertook this publication in response to a growing number of requests for information a bout how Canadians will be impacted by climate change. We believe that increased knowledge can empower Canadians and their communities. It provides opportunities to educate people about the risks and actions needed to protect the most vulnerable in our society and, ultimately, improves lives.

Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity represents the first comprehensive assessment of health vulnerabilities to climate change in Canada. It provides an up-to-date synthesis of knowledge on how the health of Canadians is affected by our climate today, and what may lie ahead under future climate change.

The goal of this publication is to raise awareness of the health risks posed by climate change among those charged with protecting health. It is hoped that the results will provide guidance to the public health and emergency management communities and support their efforts to adapt plans, policies and programs in order to prevent or reduce risks to health. The regional studies in this Assessment show how multiple sectors, levels of government, and individual Canadians play important roles in protecting health. They also demonstrate the need to understand the effects of climate change on local and regional scales. Some of the findings are not conclusive and therefore we look to researchers and decision makers in Canada to continue increasing our understanding of risks to Canadians, so that we can further the development of needed adaptations.

What started as a much smaller project grew into a larger undertaking as partners and stakeholders encouraged us to learn more about the impacts of concern to Canadians. We received valuable advice through early workshops and through the contribution of many experts during the project. I am indebted to the many individuals who shared our vision and took time to conduct research, provide expert opinions, and review draft chapters. The contribution of so many individuals from organisations and institutions across Canada is a testament to the multi-disciplinary and collaborative nature of this endeavour. Their commitment to advancing our knowledge in this area made this publication possible and I thank them for their dedication.

Jacinthe Séguin
Health Canada
Editor

FOREWORD

Climate change presents significant challenges in efforts to maintain and improve the health and well-being of people living around the world. Developed countries such as Canada are not immune to the impacts of climate hazards such as weather extremes. As health risks from extreme weather events and global warming continue, the scientific information needed to address these risks must reach health and emergency officials and individual citizens so that they can take needed measures to adapt.

This new report published by Health Canada is a timely assessment of new research on health risks posed by climate change. The theme of World Health Day in 2008 is "Protecting Health from Climate Change", which reminds us of the urgency of this issue and of the need to take necessary actions to protect those most vulnerable to the health impacts of climate change.

This Assessment draws from guidance provided in the "Methods for Assessing Climate Change and Health Vulnerabilities and Public Health Adaptation", which were the result of a multi-year collaboration among the World Health Organization, Health Canada, the United Nations Environment Programme and the World Meteorological Organization. Continued collaboration among researchers, government officials and health organizations in efforts to address the impacts of climate change is essential if we are to reduce risks to the health of the most vulnerable populations.

Findings and lessons learned from the Health Canada Assessment can benefit other countries in their investigations of existing vulnerabilities and in the engagement of the health sector in future adaptation work.

Maria Neira
Director
Department of Public Health and Environment
World Health Organization

Roberto Bertollini
Director
WHO Regional Office for Europe

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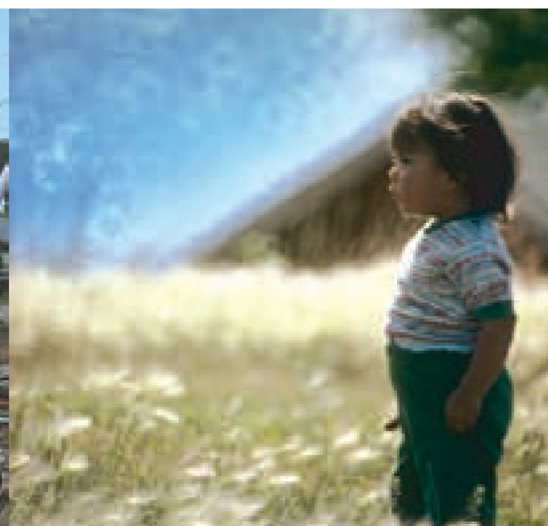

Canada

Human Health in a Changing Climate:

A Canadian Assessment of Vulnerabilities and Adaptive Capacity

Synthesis Report

AUTHORS

Jacinthe Séguin[1]
and Peter Berry[1]

1 Climate Change and Health Office, Safe Environments Directorate, Health Canada.

The authors would like to acknowledge the contribution of Benjamin Brisbois to the development of the Synthesis Report.

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E-Mail: info@hc-sc.gc.ca

HC Pub.: 4111
Cat.: H128-1/08-529E
ISBN: 978-0-662-48366-3

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.

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Lisa Stringer	Public Health Agency of Canada
John Wellner	Ontario Medical Association

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.

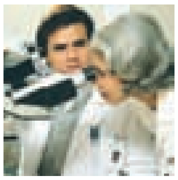
This Synthesis Report sets out the key findings of the Assessment and presents important issues common to each of the chapters: how climate-related health impacts affect Canadians today, how climate change may influence health risks in the future, which Canadians are most vulnerable to these risks, and 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.

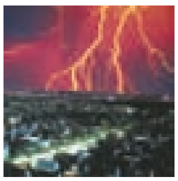
Human Health in a Changing Climate complements this study by providing decision makers with an integrated perspective on existing vulnerability to the potential health impacts of climate change, and insights on how risks can be reduced by increasing adaptive capacity. It provides information to support 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.



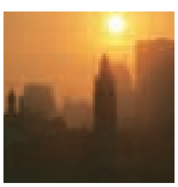
Chapter 2, *Assessment Methods*, discusses methodologies used for this Assessment, as well as their general limitations, including the topic of uncertainty. It should be noted that some chapters use methods and practices appropriate to their specific investigations, and these are discussed in detail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



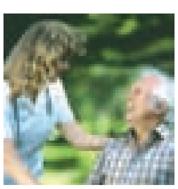
Chapter 3, *Vulnerabilities to Natural Hazards and Extreme Weather*, examines the occurrence of climate-related natural hazards in Canada. It reviews the impacts of such events on health, and the systems and measures in place to mitigate these impacts. It also proposes research directions and measures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

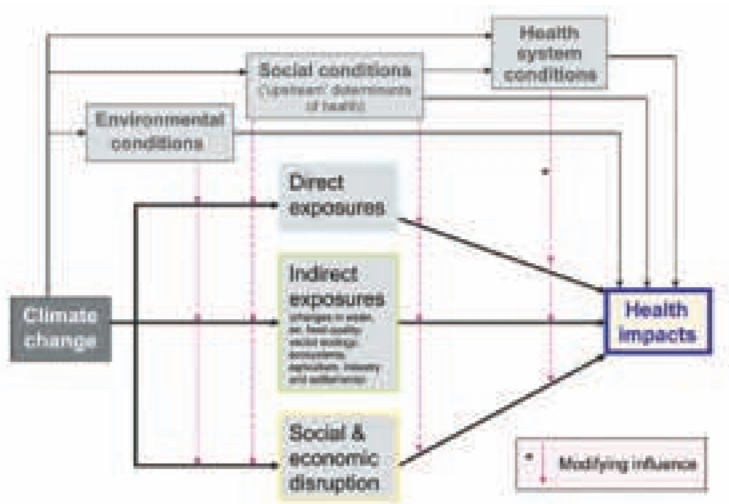
Weather – Weather is the state of the atmosphere at a given time and place with regard to temperature, air pressure, humidity, wind, cloudiness and precipitation. The term “weather” is used mostly for conditions over short periods of time.

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.

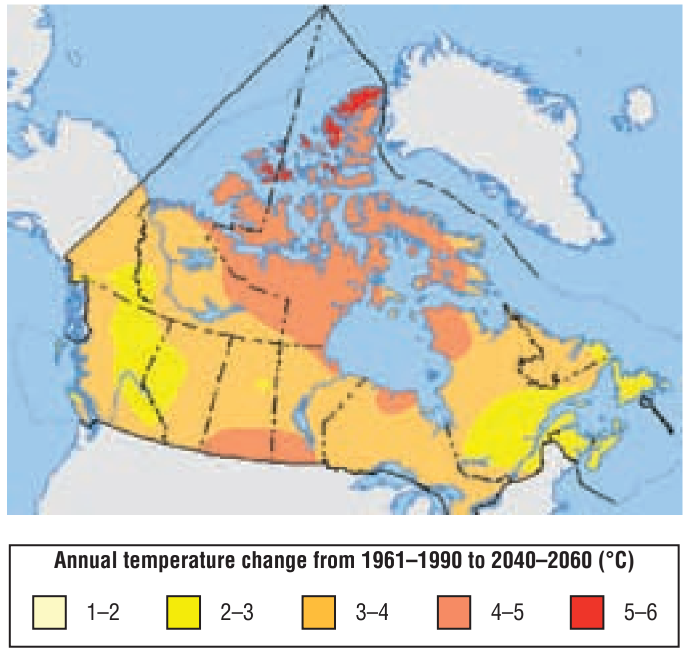
CLIMATE CHANGE PROJECTIONS FOR CANADA

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 vulnera-bilities 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.

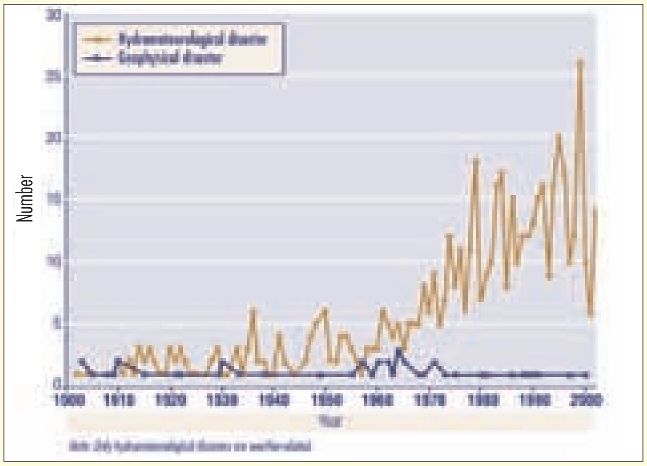
Table SR–2: Regions in Canada affected by natural hazards[3]

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.

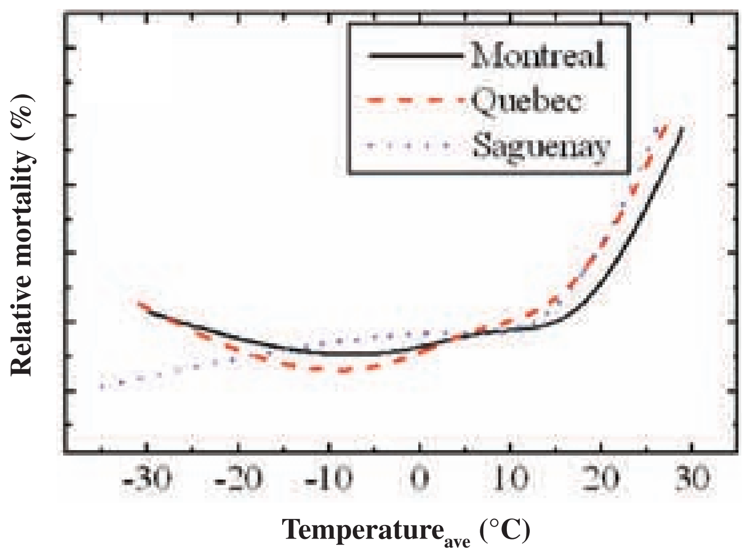
Extreme heat events pose significant risks to individuals and can be especially dangerous for children and infants, seniors and people in frail health, particularly those taking certain medications. Few studies of temperature-related mortality have been carried out in Canada. The Quebec chapter examined 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.

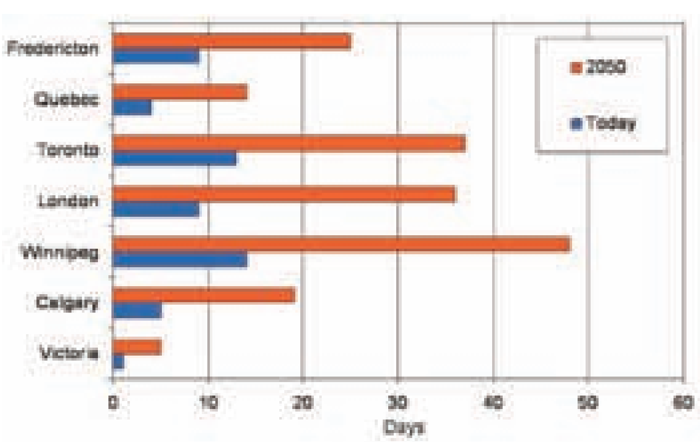
Future risks to human health

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.

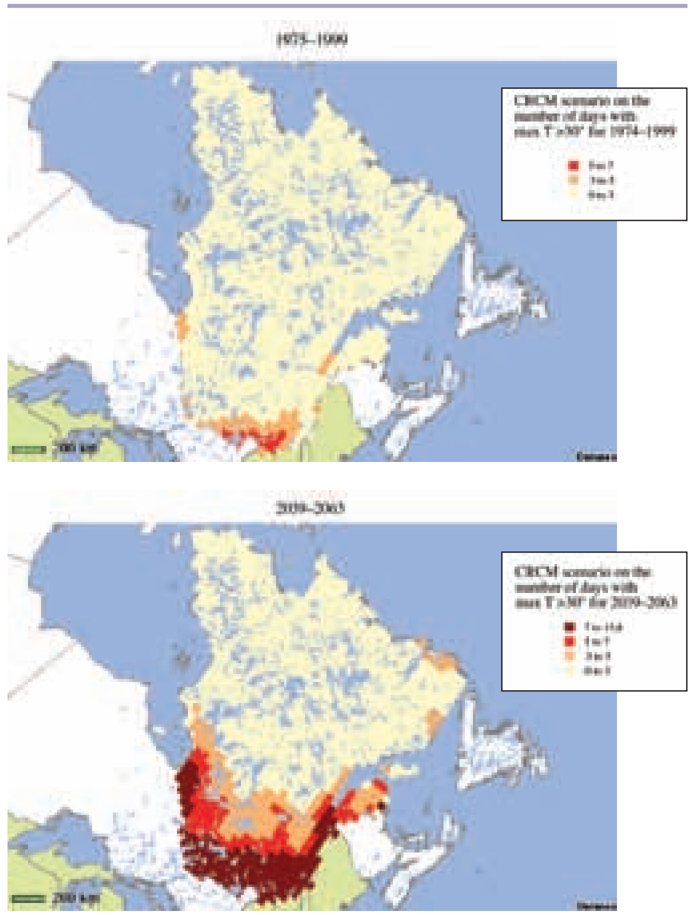
While future summer mortality rates associated with high temperatures are projected to be higher for all age groups, it is expected that the increase for the 65-and-older population cohort will be approximately two to three times greater than for individuals aged 15 to 64. This suggests that seniors 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 30°C 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.

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.

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.

Future risks to human health

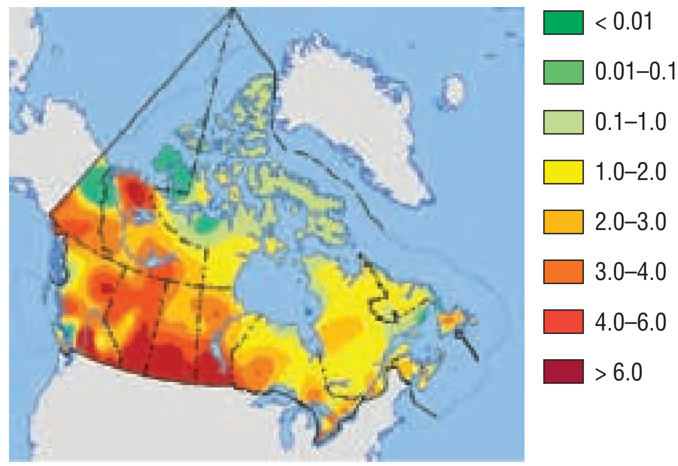
The severity and duration of air pollution episodes are projected to increase in some areas of Canada as a result of a warmer climate. This Assessment estimated changes in air pollution that would occur if there was a 4°C increase in average temperature (from 2002 levels), with anthropogenic emissions 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.

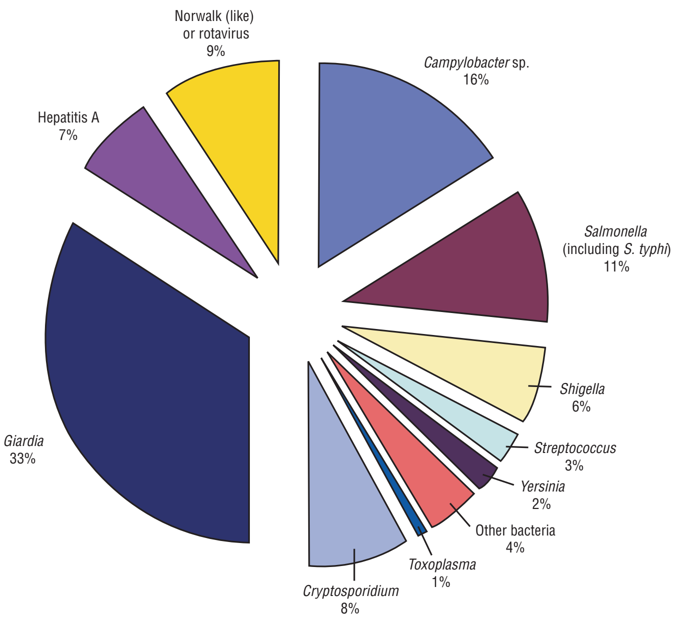
There are other concerns related to air quality, which are also likely to increase as the climate changes. Warmer summers, changes in precipitation patterns and longer growing seasons are expected to increase the types and amounts of airborne allergens in some areas, negatively affecting individuals 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.

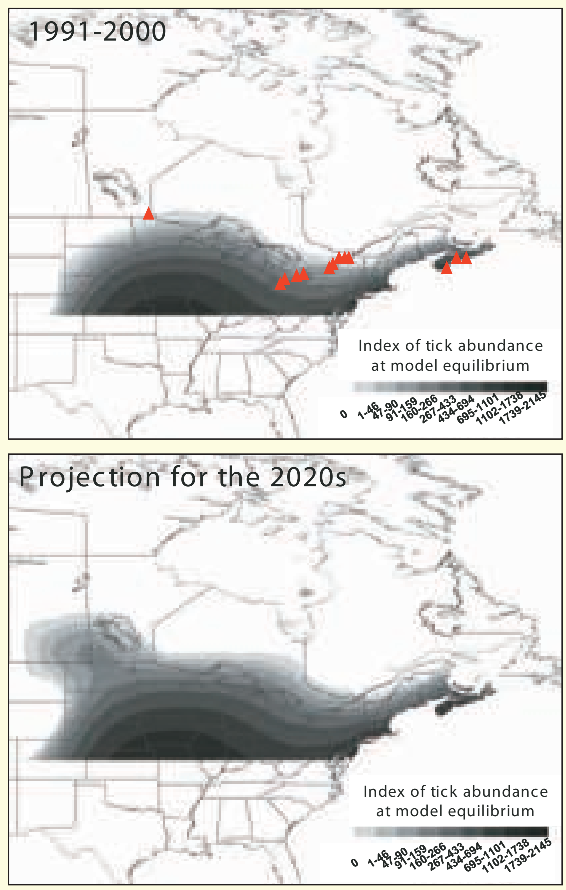
Milder winters followed by prolonged summer droughts and heat waves could favour the spread of West Nile virus and Lyme disease through changes in mosquito and tick populations. In regions of Canada where low temperatures, low rainfall, or the absence of vector habitat have restricted the transmission 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.

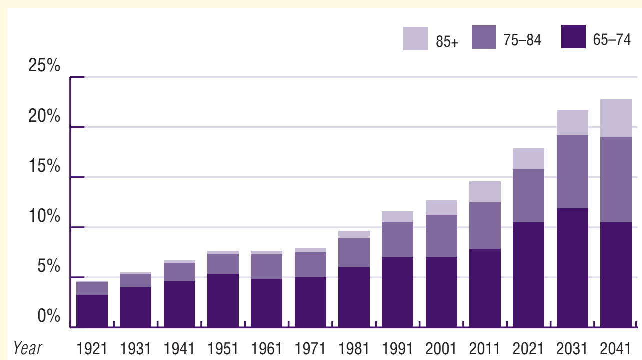
Vulnerability trends for Canada's future

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.

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.

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.

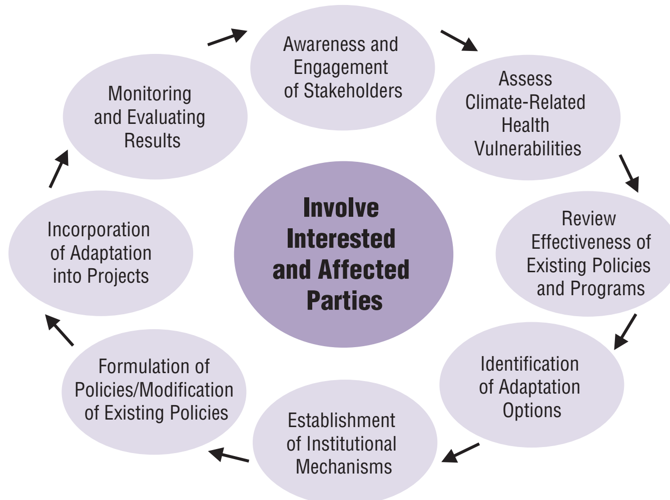
From national to local levels, recent initiatives—such as the creation of the Public Health Agency of Canada, the National Framework for Health Emergency Management, the National Disaster Mitigation Strategy, the Building Canada Infrastructure Program, the launch of the Air Quality Health Index, and 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.

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

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.

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.

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.

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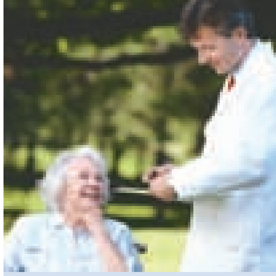
Chapter 1

Introduction

Jacinthe Séguin
Kaila-Lea Clarke



Chapter 1

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Chapter 1

1.1 CLIMATE CHANGE AND THIS ASSESSMENT

1.1.1 Introduction

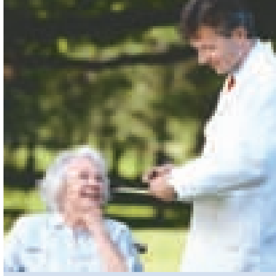
For more than two decades, findings of the scientific community have indicated that the Earth's climate is rapidly changing. The Intergovernmental Panel on Climate Change (IPCC) states that "warming of the climate system is unequivocal," and its conclusion is supported by observations of increases in 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

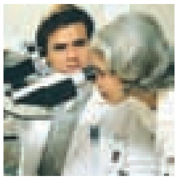
The National Steering Committee recognized the limitations of current knowledge, research capacity, and data availability and completeness. Therefore, the approach and scope of this initiative was intended to meet the following objectives:

- 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.

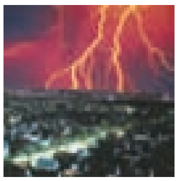
This Assessment brings together information collected through a wide range of methods (literature reviews, modelling studies, table-top simulation exercises, key informant interviews and population surveys) to present evidence of risks to health from climate change, along with vulnerabilities of concern. 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.

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.



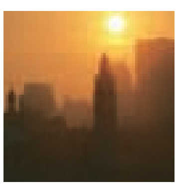
Chapter 2, Assessment Methods, discusses methodologies used for this Assessment, as well as their general limitations, including the topic of uncertainty. It should be noted that some chapters use methods and practices appropriate to their specific investigations, and these are discussed in detail in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



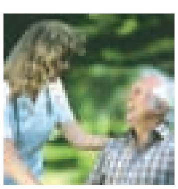
Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, examines the occurrence of climate-related natural hazards in Canada. It reviews the impacts of such events on health, and the systems and measures in place to mitigate these impacts. It also proposes research directions, policies and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

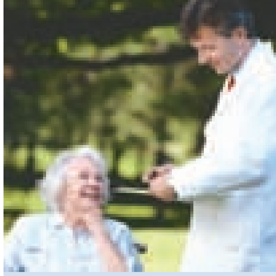


Chapter 6, Health Impacts of Climate Change in Quebec, and Chapter 7, Health Impacts of Climate Change in Canada's North, are assessments of vulnerabilities to health in two regions of the country; both cover the full scope of the issues addressed in this Assessment. These regions were selected because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

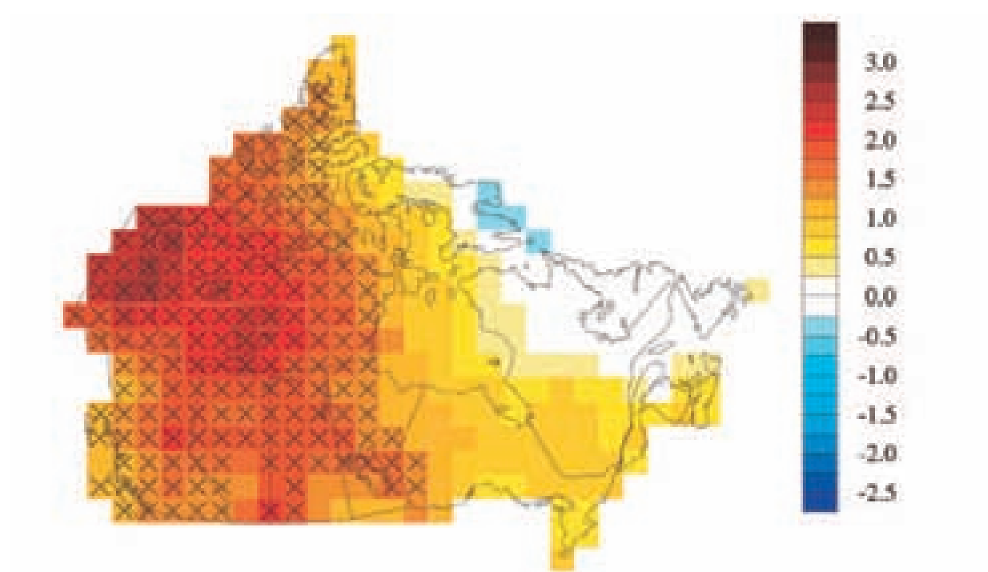
The geography of Canada is vast and diverse, covering 48 degrees of latitude from Pelee Island in the south to the Arctic Ocean and extending across from the Atlantic to the Pacific oceans. This land mass has a varied topography and considerably different ecosystems and climate regimes. The Canadian 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).

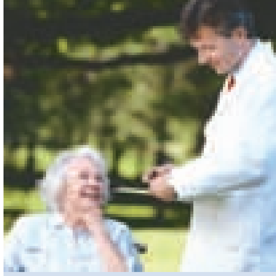
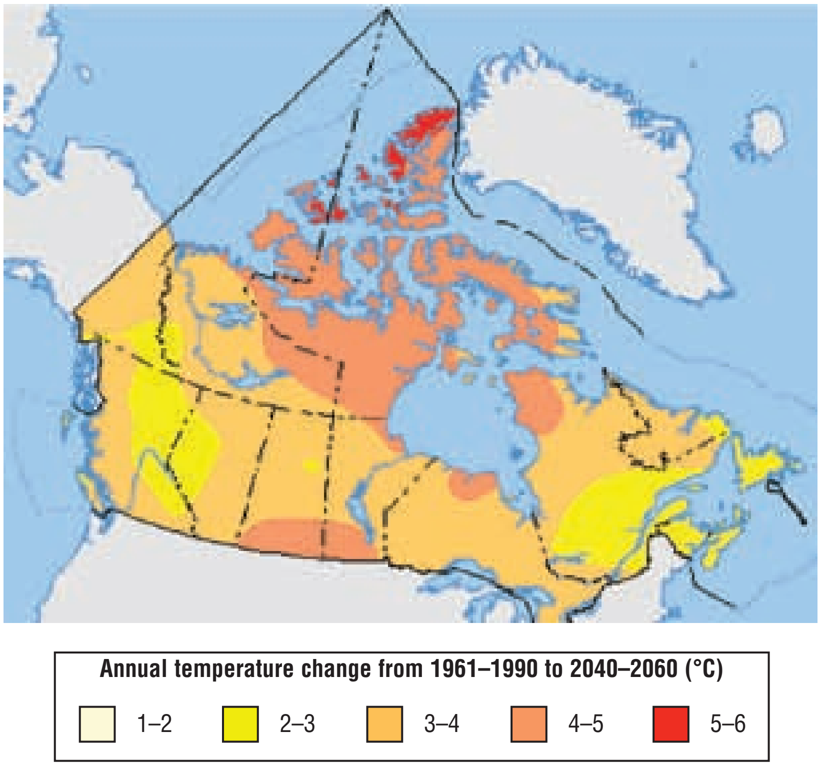
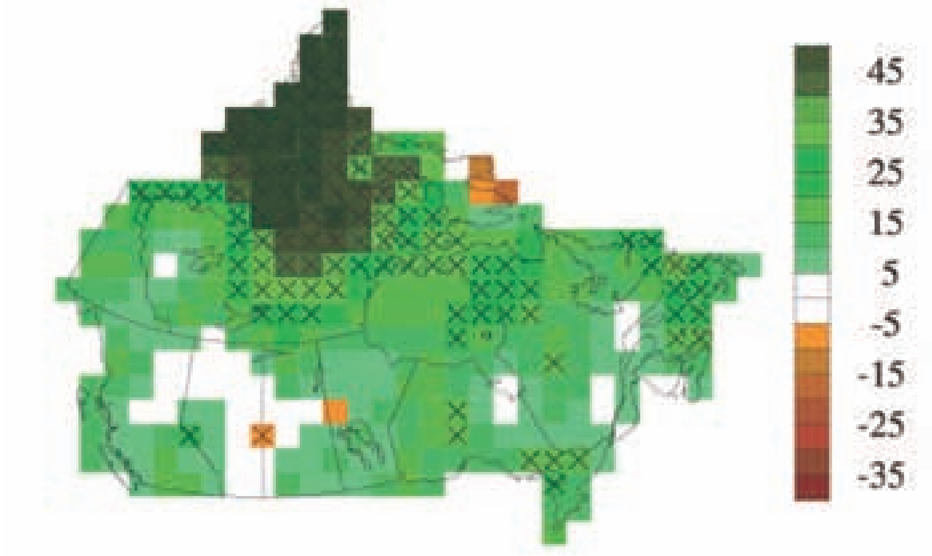


Figure 1.2 National annual temperature scenario 2050: A simulation of projected changes in annual mean temperatures for Canada for the period 1961–90 to 2040–60



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

Annual precipitation change from 1961–90 to 2040–60 (%)

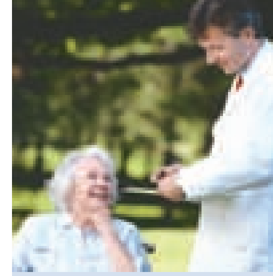
-10–0 | 0–10 | 10–20 | 20–30

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

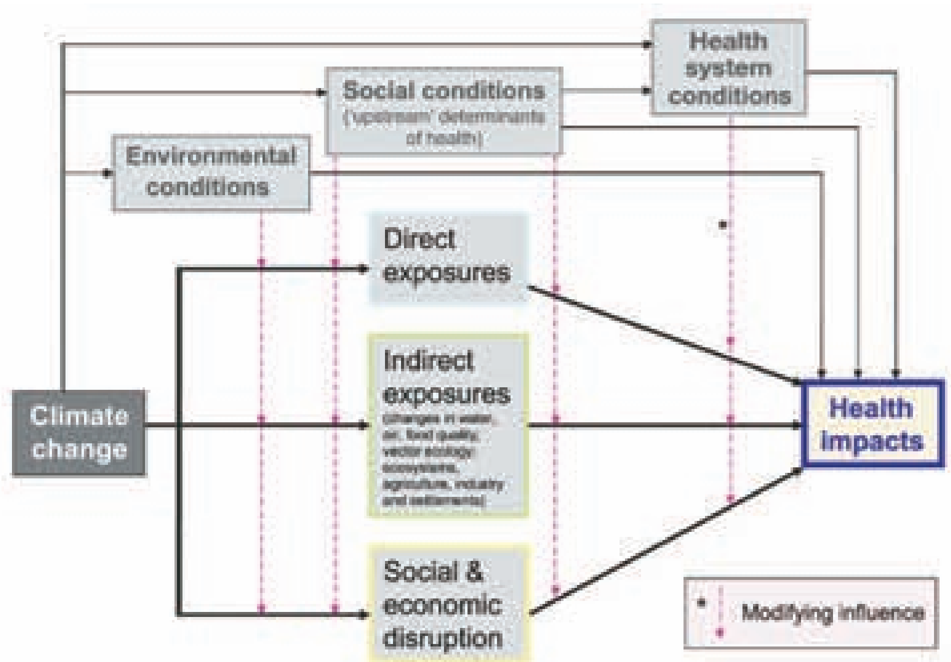
The World Health Organization's definition of human health as "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (WHO, 2006, p. 1) is widely accepted and has influenced the development of approaches to managing population health worldwide. 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

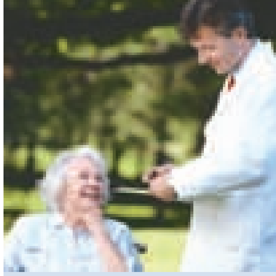
- Income and social status
- Social support networks
- Education and literacy
- Employment/Working conditions
- Social environments
- Physical environments
- Personal health practices and coping skills
- Healthy child development
- Biology and genetic endowment
- Health services
- Gender
- Culture

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.

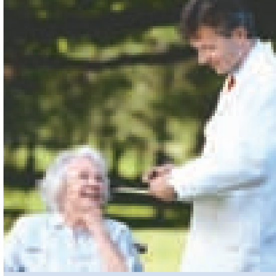
Transportation is another aspect of Canadian society highly influenced by climatic conditions. For many northern residents, the unreliability of "snow roads" because of milder winters has substantial implications in terms of access to food, goods and services, and employment. Weather conditions can contribute 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

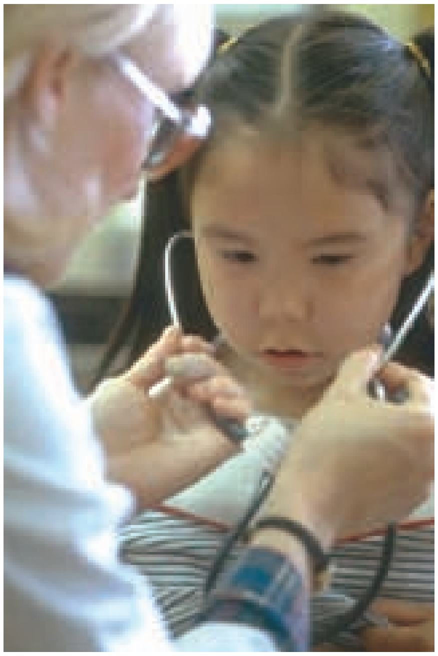
Source: Adapted from Health Canada, 2005b.



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).

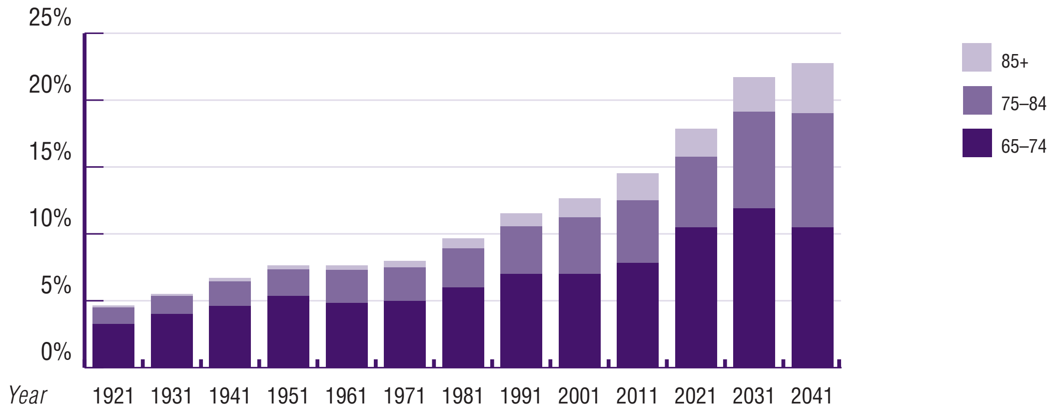


The high level of population health in Canada provides a strong foundation for coping with the diverse stresses that climate change will place on health and well-being. Healthy populations are more resistant to infection and disease, better able to recover from injury and less likely to fall ill under 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

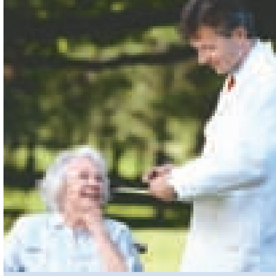


Source: Government of Canada, 2002.

> **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).

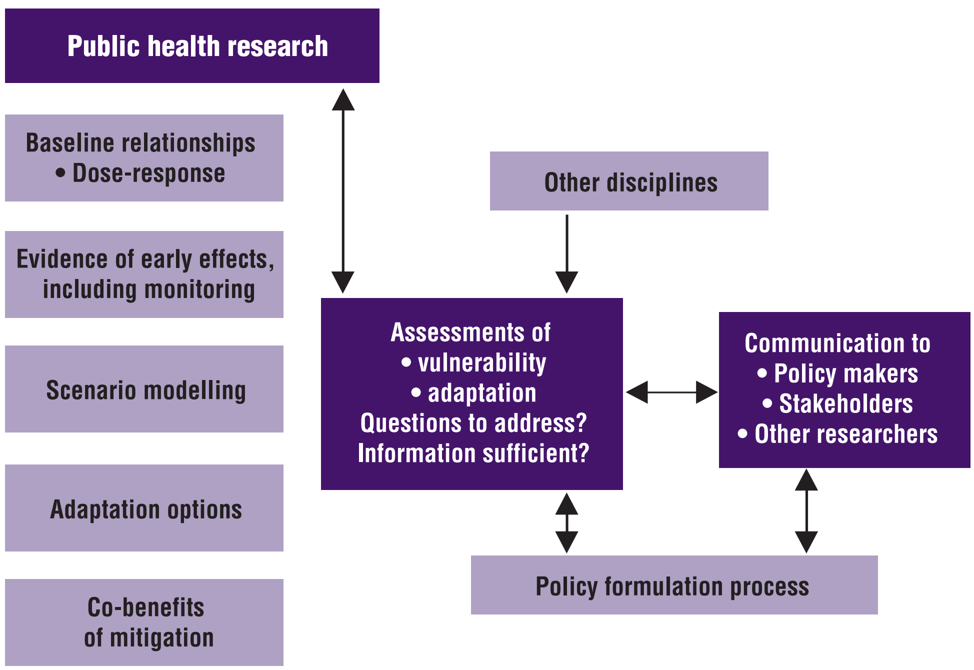
Social factors also contribute to vulnerabilities. A few studies discovered that older men suffer more from isolation, and as a result may be vulnerable to climatic extremes because they do not have the ability to seek the assistance of family members or community volunteer organizations (Klinenberg, 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.

Chapter 1

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

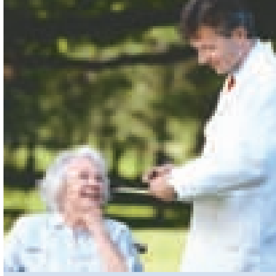
Adaptive capacity refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences (IPCC, 2007a).

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.

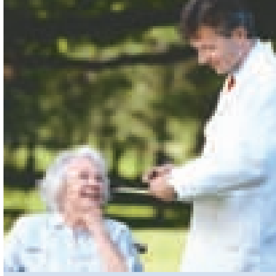


The reduction of GHG emissions is important to limiting the rate and magnitude of future climate change. Nevertheless, even if global efforts to reduce GHGs are successful in the future, climate change and its associated impacts are now expected to be unavoidable (IPCC, 2007c). Consequently, current 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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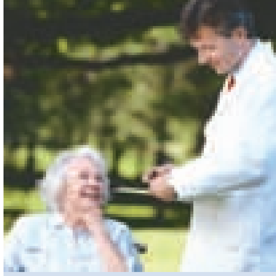

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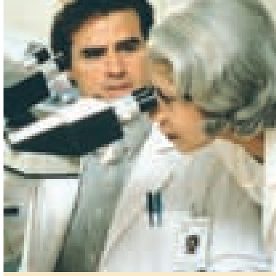
Chapter 2

Assessment Methods

Peter Berry
Kaila-Lea Clarke
Colin L. Soskolne



Chapter 2

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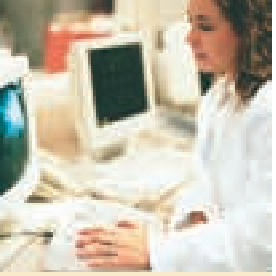
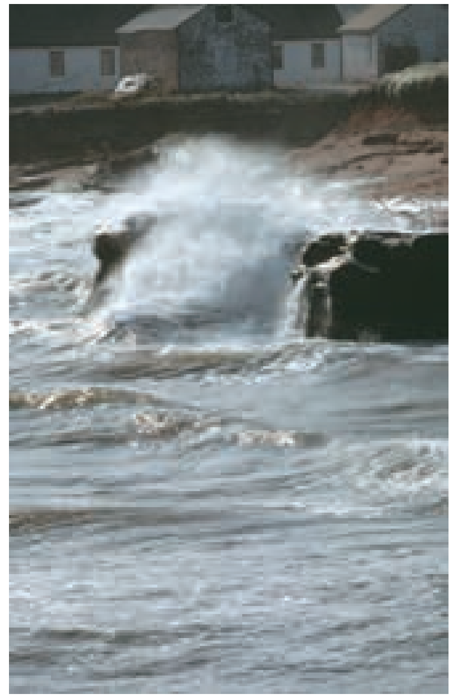


Chapter 2

2.1 INTRODUCTION



Assessing the health risks associated with climate change and variability requires understanding both the vulnerability of a population and the capacity of the population to respond to the new conditions that arise. Several countries have completed some form of assessment of climate-related health risks (e.g. United States, India, Portugal, United Kingdom, Australia)[1] as part of their national communications to the United Nations Framework Convention on Climate Change. However, few of these assessments specifically identify existing vulnerabilities and adaptation options (Kovats et al., 2003a). Systematic approaches for identifying health risks, vulnerable populations and adaptation options are still being refined.

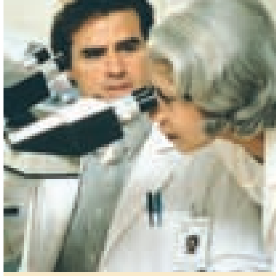
Vulnerability is a broad concept; the Intergovernmental Panel on Climate Change (IPCC) defines it as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007, p. 21). Vulnerability to health impacts is a function of the sensitivity and exposure of populations to climate-related risks and the ability to manage these risks. Increasing adaptation measures and adaptive capacity helps to manage risks and reduce adverse health outcomes. Generally, the vulnerability of a population to climate-related health risks can be influenced by the following key factors of adaptive capacity: economic resources, technology, information and skills, infrastructure, institutions, equity and population health status (Grambsch and Menne, 2003).[2]

To assess the health risks of climate change, a number of important methodological issues must be considered and addressed. Challenges associated with the selection and application of methods for understanding human health vulnerabilities at the national scale arise because the impacts of climate change in Canada are expected to differ considerably according to the geographical location and the sensitivity of exposed populations. Because Canada has regions with dramatically different natural environments, and social and economic characteristics (e.g. north versus south), the methodologies for assessing vulnerabilities of populations need to address these variables.

In addition, there are also methodological challenges that arise from limited understanding of the complex pathways by which climate change can affect health, as well as from the timing of specific impacts. The pathways can be both direct and indirect and the severity of some impacts may not be felt for decades or longer. Direct and indirect health impacts may result from changes in day-to-day weather (e.g. deaths and illnesses from a heat wave) or from changes in ecosystems occurring over months to years (e.g. emerging infectious diseases from habitat alterations). Such impacts are often mediated through the effects of other

1 A more complete list of national impact assessments of climate change can be found in the Health Chapter of the *Fourth Assessment Report* of the IPCC (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).

2 See Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada, for a more detailed discussion of vulnerability and adaptive capacity.



important determinants of population health (e.g. health care system, socio-economic factors). Both direct and indirect health impacts are discussed in *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity* (this Assessment).

For some health concerns (e.g. vector-borne and zoonotic diseases), assessments are supported by methods that are relatively well established. For others (e.g. food security, impacts on vulnerable populations), methods are underdeveloped or hampered by shortages of available data (Kovats et al., 2003b). An assessment of vulnerability to climate change impacts must take these factors into account by moving beyond conventional human health risk assessment approaches to investigate impacts that could occur in the future (Santos et al., 2002). Models, scenarios and other tools, designed to explore a range of possible futures, are used in vulnerability assessments to better understand future climate change impacts. Future projections of climatic conditions do, however, lack resolution over small geographical areas, and they may not represent the rate at which the changes may occur with a high enough degree of confidence to inform decision making. Those conducting vulnerability assessments need to account for the strengths and weaknesses of existing methods and tools.

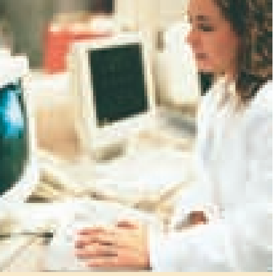
2.1.1 Considerations Relevant to the Assessment Approach

In Canada, an investigation of climate change and health issues is included in the *Canada Country Study: Climate Impacts and Adaptation* (Maxwell et al.,1997), *Climate Change Impacts and Adaptation: A Canadian Perspective* (Lemmen and Warren, 2004) and in *From Impacts to Adaptation: Canada in a Changing Climate 2007* (Lemmen et al., 2008). Each of these reports is based on literature reviews and provided an overview of key health risks associated with climate variability under changing climatic conditions. However, owing to the limited scope of the human health component of the reports, little information is included on existing vulnerabilities of specific populations and regions, and on the capacity of governments and communities to take the needed actions to adapt.

The complexity of biophysical and social processes affecting human health requires that health assessments employ a broad range of health data, and analytical methods and tools, as well as draw upon interdisciplinary collaboration among researchers from many fields of expertise. Interdisciplinary collaboration unites the efforts of specialists from various domains: environmental science, medicine, public health, climate sciences, and social and behavioural studies (DesJarlais et al., 2004).

A range of both qualitative and quantitative methods and tools can be employed depending on the purpose of the assessment and the type of data available. Examples include literature reviews, expert judgement, ecological studies, geographic information systems, time-series analysis, risk assessment, community and stakeholder consultation, statistical models and scenario analysis.[3] The choice of whether to use qualitative or quantitative methods, or a combination of both, depends on the level and type of knowledge required by policy makers (Kovats et al., 2003b). Many assessments integrate both types of methods.

3 For example, Downing and Patwardhan (2005) provide a generic toolkit for climate change vulnerability and adaptation assessments.



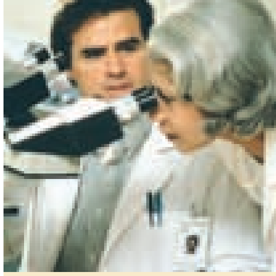
Whatever methods are chosen, they should support the goal of identifying the potential health risks of climate change, the most vulnerable populations and regions, and the measures required to protect health. A comprehensive assessment provides information on:

- current distribution and burden of climate-sensitive diseases;
- interactions among multiple climate and non-climate-related stressors (e.g. heat waves, air pollution, power failures, drought);
- estimates of the future potential health risks of climate change using scenarios of future climate change, population growth, community infrastructure, and other factors;
- likely threshold or dose-response effects that indicate whether, and how rapidly, the level of response increases or decreases with exposure to the hazard;
- health implications of the potential impacts of climate change on other sectors;
- effectiveness of current actions in place to reduce the burden of any particular health outcome;
- future coping capacity of individuals and their communities (e.g. economic resources, health and social services); and
- identification of short-term, medium-term and longer-term adaptation measures required to reduce current and future vulnerability.

2.2 OPTIONS FOR ASSESSING VULNERABILITY

Conventional environmental health risk assessment frameworks provide important methodological tools (e.g. hazard assessment, stakeholder engagement) for climate change and health vulnerability assessments. But these frameworks do not provide sufficient guidance for vulnerability assessments because they cannot account for the multiple interrelated causes of disease and the various feedback mechanisms that often limit the predictability of health outcomes (Bernard and Ebi, 2001). Several guidance documents and conceptual frameworks have been developed that provide general direction for the application of methods to assess vulnerability to the health impacts of climate change and to develop adaptation strategies and prioritize options (e.g. IPCC *Technical Guidelines for Assessing Climate Change Impacts and Adaptations*: Carter et al., 1994; *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*: Feenstra et al., 1998; *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*: Lim et al., 2005).

A literature review by Füssel and Klein (2004) surveyed existing guidance documents and conceptual frameworks related to adaptation to climate change, and evaluated their applicability to national and regional policy strategies aimed at reducing climate-related health effects. Many of the current approaches, such as the IPCC technical guidelines (Carter et al., 1994), were found to have significant limitations in their applicability to climate change and health vulnerability assessments. The authors reported that *Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change* (Kovats et al., 2003b) (described later in the text) is the "single most important guidance document for climate change adaptation assessment for human health" (Füssel and Klein, 2004, p. 82).

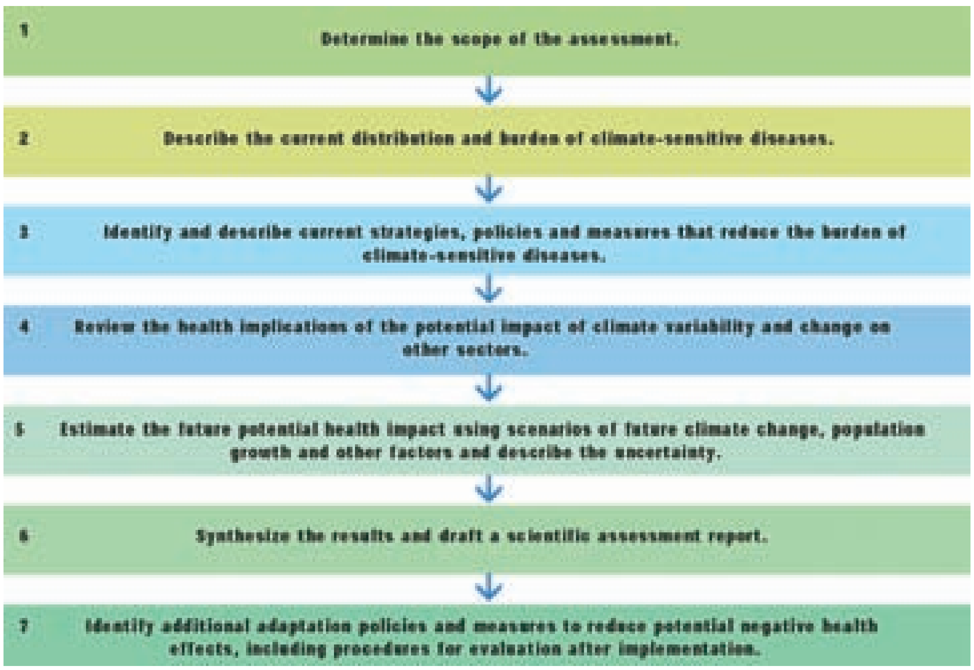


Chapter 2

2.2.1 Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change

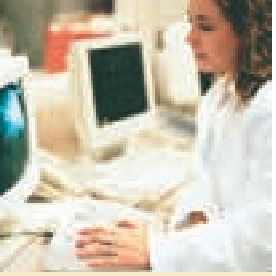
Kovats et al. (2003b) provided a basic approach for all countries to assess and better understand the risks of climate change to human health in regions throughout the world. They provided advice for dealing with the complexity of the subject matter and existing scientific uncertainties, outlined the strengths and weaknesses of existing tools and methods, and offered practical guidance for undertaking assessments to governments, health agencies, and environmental and meteorological institutions in both industrialized and developing countries. Figure 2.1 illustrates the steps in assessing vulnerability and adaptation as put forward by Kovats et al. (2003b).

Figure 2.1 Steps in assessing vulnerability and adaptation



Source: Kovats et al., 2003b

The approach advocated in the document by Kovats et al. (2003b) integrates activities aimed at understanding current vulnerability and adaptive capacity with efforts to increase knowledge of projected future impacts of climate change. Such information directs actions to revise, reorient and/or expand public health strategies, policies and measures to protect the health of populations. For a range of health outcomes, methods are presented to aid in the evaluation of evidence that climate change is affecting morbidity and mortality. Methods are also selected to aid in the projection of future impacts, and identify adaptation strategies, policies and measures to reduce current and future negative effects.



2.3 APPROACH AND METHODS USED FOR *HUMAN HEALTH IN A CHANGING CLIMATE: A CANADIAN ASSESSMENT OF VULNERABILITIES AND ADAPTIVE CAPACITY*

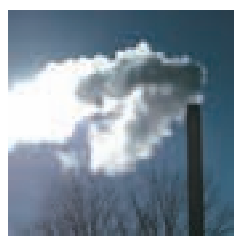
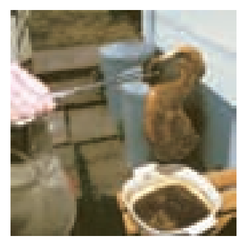
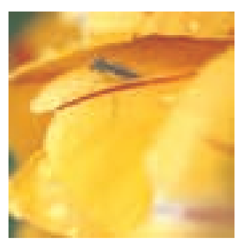
2.3.1 Assessment Approach

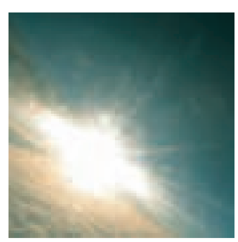
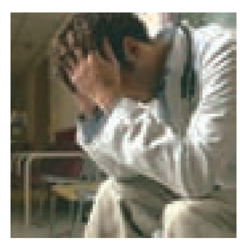
To the extent possible, the approach used in this Assessment followed the approach in *Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change* (Kovats et al., 2003b). It combined an investigation of vulnerabilities to current weather and climate variability with an exploration of specific health risks (e.g. air pollution health risks) that are anticipated under future climate scenarios. The assessment of vulnerability varied considerably for each chapter, given differences in data availability and in the focus and purpose of the respective chapters. Those chapters that examined specific health issues arising from climate change focussed the discussion of vulnerability on specific groups and populations within Canada that are most at risk.[4] Chapters dealing with specific regions (i.e. Quebec and the North) provided a broader assessment of vulnerability to the impacts through an examination of current adaptations and ability to cope with the multiple climate-related health risks within the respective regions. Some of these findings are expanded upon in Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada, which provides a national perspective on vulnerability by highlighting trends in exposure to climate-related hazards and the sensitivity of individual Canadians, and by examining the status and effectiveness of key adaptations to reduce health risks. This Assessment went beyond a basic assessment; it not only reported on the available information about potential vulnerabilities in Canada through literature reviews, it also collected new data and research to quantify impacts and evaluate current responses (e.g. simulation exercises, informant interviews).

Determination of structure and scope

Existing literature identifies several potentially adverse health risks of climate change across Canada (Maxwell et al., 1997; Health Canada, 2003; McMichael et al., 2003; Lemmen and Warren, 2004):

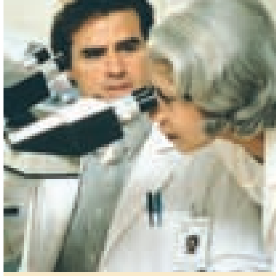
- air quality-related health effects;
- water-, food-, vector-, and rodent-borne diseases;
- health effects of extreme weather events;
- health effects associated with stratospheric ozone depletion; and
- socio-economic impacts (e.g. economic and occupational losses).

Through consultative mechanisms, including steering committee meetings and three expert workshops, the structure and scope of this Assessment were determined. Three areas that have important implications for human health—air pollution, water-, food-, vector-, and rodent-borne diseases and natural hazards related to climate variability—were chosen for investigation

4 Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, goes somewhat further by highlighting the characteristics that increase the vulnerability of communities, such as deteriorating infrastructure or factors related to urban design (e.g. large areas of concrete, limited green spaces).



in this Assessment based on the following criteria: (1) availability of data and analytical tools, (2) existing burden of disease, (3) existence of knowledge gaps, (4) availability of scientific expertise to address issues, and (5) the extent to which the health sector can adapt.

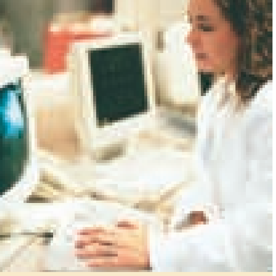
The investigation of air pollution related to climate variability provided findings that are relevant to many parts of Canada, given that many regions and several highly populated communities currently experience health risks from poor air quality. Expected impacts from climate change on air quality have been highlighted as a key issue for North America (McMichael et al., 2003; Confalonieri et al., 2007; IPCC, 2007). Literature reviews of health risks within Canada from water-, food-, vector-, and rodent-borne diseases, as well as natural hazards related to climate variability (e.g. heat waves, storms, wildfires) were also conducted in the course of this Assessment. In addition, two regional health assessments—one for the Canadian North and one for Quebec—were carried out to allow health decision makers to better understand how multiple health issues interact on one population, and to gauge the adaptive capacity of the region as it responds to several, and sometimes confounding, health issues. The North was chosen because it is currently experiencing severe impacts of climate change and because the *Arctic Climate Impact Assessment,* which was released in 2004, provided a body of knowledge from which to draw (Hassol, 2004). The province of Quebec was chosen because, at the time of writing, it had the institutional research capacity and expertise to carry out the research through key public health agencies in that province (e.g. Institut national de santé publique du Québec) and through the Ouranos Consortium, which includes Government of Quebec ministries, universities, federal agencies and industry partners, collaborating to increase understanding of climate change impacts and needed adaptations in Quebec.

Although this Assessment did not examine vulnerability to the health risks of climate change in all parts of Canada, it is possible to extrapolate specific findings to other regions that may share similar climate-related hazards. In addition, it provides lessons learned about how to conduct climate change and health vulnerability assessments for those regions and individual communities in Canada that may choose to undertake their own assessments in the future.

Key assessment components included:

- assessing health risks at the national scale related to decreased air quality, including an investigation of current risk management strategies;
- assessing a range of health risks and vulnerabilities at a local scale in Canada's northern communities and for people living in Quebec;
- assessing the capacity of communities and governments to adapt to health risks, including local-scale case studies;
- identifying populations most vulnerable to climate change;
- identifying knowledge gaps that need to be investigated further to fully understand the possible impacts of climate change on health; and
- literature reviews of water-, food-, vector-, and rodent-borne diseases and natural hazards related to climate variability.

Authors for each chapter drew upon input from experts and practitioners, working in a wide range of disciplines, who were engaged in collaborative research projects, as well as input gained from the peer review process. For example, Chapter 4, Air Quality, Climate Change and Health, involved governmental and non-governmental researchers with expertise in epidemiology, environmental health sciences, climate modelling and atmospheric sciences, in the



analysis of the potential impacts of climate change on future air quality and risks to human health. Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada, drew upon expert input from researchers in the fields of public health, health care system renewal, emergency management, natural hazards assessment, sociology and behavioural sciences to explore the ability of governments and communities to adapt to climate change health risks.

Assessment oversight

Oversight for this Assessment, including the peer review process, was provided by a multi-stakeholder National Steering Committee, comprising officials involved in these issues at local, regional and national levels, and representatives from governmental and non-governmental organizations. It is noted, however, that broad consultation with stakeholders, such as local medical officers of health, voluntary organizations and provincial health representatives did not take place, but would provide added value in future assessments.

2.3.2 Assessment Methods

This Assessment employed a broad range of health data, and analytical methods and tools. Key methods employed included climate models, climate scenarios, expert judgement, epidemiology, ecological studies, literature reviews and stakeholder consultations.

Data, methods and tools used for *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilitites and Adaptive Capacity*

Climate model: A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and which accounts for all or some of the known properties. Models may vary in complexity. As research tools, they are applied to study and simulate the climate, but are also used for operational purposes including monthly, seasonal and inter-annual climate predictions.

Climate scenario: A plausible and often simplified representation of the likely future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change and often serving as an input to impact models.

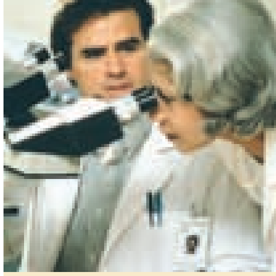
Expert judgement: Statements, which represent a process of evaluation that can be described as a set of conditions and criteria, by someone widely recognized as a reliable source of knowledge, technique or skill and whose judgement is accorded authority and status by the public or their peers.

Epidemiology: The science of public health and preventative medicine that studies the distribution and determinants of health-related states or events in specific populations, and that applies study findings to control and/or mitigate health problems.

Ecological study: An epidemiological study which seeks to find population- or community-level associations between exposure and the occurrence of disease.

Literature review: A comprehensive survey of publications that aims to critically analyze, summarize and compare prior research in a specific field of study.

Stakeholder consultation: Canvassing of views of stakeholders, which may include governments, non-governmental organizations, research institutes and private entities that focus on the issue being investigated, in the process of developing useful information, often through forums, roundtables and advisory bodies.



Strengths and limitations of the key methods and tools used for this Assessment are shown in Table 2.1. More detailed descriptions of specific methods used by the authors to examine climate change risks to health are presented in the respective chapters.

Table 2.1 Strengths and limitations of assessment methods and tools[5]

Study Method or Tool	Assessment Application	Strengths of Application	Limitations of Application
Climate Models and Scenarios	Chapter 4, Air Quality, Climate Change and Health: Modelled the impact of an increase in temperature of 4°C (2002 as the base year) on concentrations of ground-level ozone and particulate matter ($PM_{2.5}$) for all of Canada in 2080 using the Meteorological Service of Canada's Unified Regional Air-quality Modeling System (AURAMS), and then impacts on human health using Health Canada's Air Quality Benefits Assessment Tool (AQBAT).	Quantitative estimates of future health risks were derived; these were useful for developing adaptation measures to protect human health.	Chapter 4 used a single temperature increase of 4°C (not a range of possible increases) to assess selected changes arising from climate change. It also used a single 3 month time period for the analysis based on 2002 conditions, subject to the 4°C increase. Analysis in Chapter 4 was limited due to uncertainty about future exposure to air pollution (e.g. people spending more time outdoors) and other factors that may affect air quality as a result of climate change (e.g. wildfires, modification of biogenic and anthropogenic emissions).
	Chapter 6, Health Impacts of Climate Change in Quebec: Projected morbidity from heat waves for the certain cities and administrative areas in Quebec using the HadCM3 general circulation model and downscaling techniques. Projections were made for the 2020, 2050 and 2080 timeframes.	Statistical downscaling techniques permitted the use of global general circulation model data at more local scales in Quebec (e.g. city level). Modelling of heat health effects allowed for the identification of impacts for different cities and regions.	Limitations in weather data for administrative areas made projections of impacts on mortality more difficult.
Expert Judgement	Key informant interviews were used in research projects for Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather; Chapter 4; Chapter 6; and Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada.	Qualitative findings complemented the analyses conducted through literature reviews. Surveys and consultations provided a stakeholder engagement and awareness-building function. Provided up-to-date and relevant information on adaptation initiatives of health sectors in Canada.	Small number of interviewees for Chapters 3, 4 and 8 limited the ability to generalize findings. Findings were subjective in nature.

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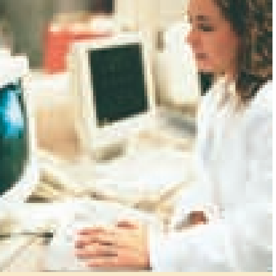
5 Note: Information on the general strengths and weaknesses of these, and other methods and tools for assessing climate change and health vulnerability can be found in Kovats et al. (2003b) and Lim et al. (2005).



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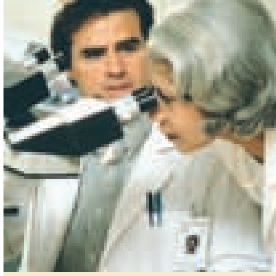
Study Method or Tool	Assessment Application	Strengths of Application	Limitations of Application
Epidemiology/ Ecology Studies	All chapters reported on results of epidemiology and/or ecology studies recently completed on climate change and health issues in Canada. The synergistic effects of heat wave and air pollution episodes (particulate matter [$PM_{2.5}$] and ground-level ozone) were investigated for Chapter 4.	Chapters 4 and 6 provided quantitative estimate of impacts. Chapters 4 and 6; and Chapter 7, Health Impacts of Climate Change in Canada's North, used these studies for understanding the risks associated with vulnerabilities in specific population groups. Quantitative estimates of future health risks were used to identify adaptation measures for protecting human health (e.g. Chapters 4 and 6).	Constraints on application of this method included the costs associated with, and the time-consuming nature of, these studies. Insufficient health data and/or relevant climate data in Canada meant that associations between current and future climate hazards and health outcomes could not be rigorously tested (e.g. Chapters 3 and 7; and Chapter 5, Impacts of Climate Change on Water-, Food-, Vector- and Rodent-borne Diseases). Insufficient understanding of system dynamics.
Literature Review	Used in all chapters of the Assessment. Focus was on new studies and findings released since *Canada Country Study: Climate Impacts and Adaptation* (Maxwell et al.,1997). Included the use of "grey" literature and policy reports in select chapters, particularly for Chapters 7 and 8. Reviews of existing documentation of traditional and indigenous knowledge, and observations of climate changes and health risks were conducted for Chapter 7.	Provided quantitative and qualitative analyses. Long-term records were accessed through electronic databases (e.g. Medline, Webscience, etc.). Analysis used descriptive information not found in traditional databases.	For some chapters, too few studies are available to characterize the level of risk to health faced by specific populations and regions in Canada from climate change (e.g. Chapters 3 and 5). Research on climate change and health adaptation measures and their effectiveness is particularly sparse.
Stakeholder Consultation	A multi-stakeholder steering committee provided oversight for the Assessment. Expert workshops were held to inform Chapters 3, 4 and 8. An advisory committee provided oversight for Chapter 6. Government authorities and individual citizens at local and sub-regional levels were consulted, and current perceptions and observations of climate changes and impacts over the province were assessed for Chapter 6.	Consultations built on engagement and awareness of issues. Supported making assessment results responsive to needs of user community. Accessed a wide range of scientists, experts and practitioners to increase credibility of results. Community consultations provided information based on direct observations of the environment by the general population and local managers for the Canadian North and Quebec.	Time consuming to ensure representation of all relevant stakeholders. Results were largely qualitative and influenced by factors affecting individual and collective perceptions, and understandings of environmental change (e.g. age, gender, lifestyle, health status, income, etc).

Note: Information on the general strengths and weaknesses of these, and other methods and tools for assessing climate change and health vulnerability can be found in Kovats et al. (2003b) and Lim et al. (2005).



2.4 UNCERTAINTY

Uncertainty is an inherent component of science. However, climate change introduces new challenges when identifying, assessing and managing health risks. Major sources of uncertainty in this Assessment resulted from knowledge gaps related to the biological and physical processes by which climate affects health as well as from difficulties inherent in estimating health impacts associated with projected climate trends. Uncertainty also resulted from incomplete knowledge about system dynamics, including a lack of information regarding processes operating on a range of scales—from local to national—that determine the capacity of individuals, communities and governments to adapt to climate variability and change.

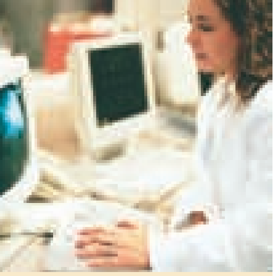
Uncertainty must be addressed in assessments of vulnerability in order to better inform policy. When reporting uncertainties, some science assessments adopt a probability-based nomenclature for expressing likelihood and/or confidence, such as the *Fourth IPCC Assessment Report* (IPCC, 2007) or the *Arctic Climate Impact Assessment* (Hassol, 2004). Although the IPCC approach is recommended in *Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change* (Kovats et al., 2003b), it was neither practical nor meaningful to adopt a standardized probability-based terminology for all chapters in this Assessment. This was due to the varying level of analysis used to assess and report health outcomes in each chapter, which was based upon available data and existing scientific studies. The qualitative statements of likelihood and confidence within this Assessment reflect the information that was available on any specific topic, as well as the use of expert judgement. In general, authors were able to express greater confidence and likelihood when the quantity and quality of the research available on the issues were high.

Improved understanding of existing vulnerabilities and the expected health impacts requires stronger health impact data and further progress in addressing existing knowledge gaps. Examples of key areas of uncertainty regarding the findings of this Assessment include:

- magnitude of expected increases in future air pollution and health risks;
- magnitude of expected stresses and pressures on the health care system and social services from a rise in climate-related health impacts; and
- degree of potential vulnerability of Canadians to climate change health impacts, given uncertainty in future demographic and health trends (e.g. age, chronic health, access to health services), and projected future exposures to climate-related hazards.

2.5 LESSONS FOR FUTURE ASSESSMENTS

This study constitutes one of the first assessments of impacts on health and well-being and vulnerabilities associated with climate change that draws extensively from the approach highlighted by Kovats et al. (2003b). It is the most comprehensive climate change and health assessment undertaken to date within Canada. As illustrated in Table 2.1, a wide range of methods were employed to examine the vulnerabilities of Canadians to climate variability and change. Application of these methods has produced new insights about the threats to the health and well-being of Canadians posed by climate change. However, time, research capacity and the availability of health data constrained the ability of authors to conduct comprehensive studies of all the potential climate change and health vulnerabilities in Canada.



Chapter 2

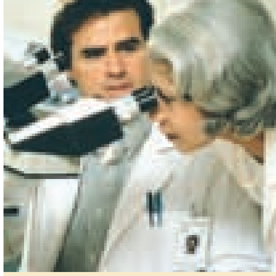
Extensive literature reviews, database searches and expert interviews were instrumental in pulling together, for the first time, baseline data and information on the magnitude of climate hazards, and the number of illnesses and deaths in Canada associated with key risks to health from climate change. For example, Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, presents information on the current health impacts of avalanches, rock-, mud- and landslides, debris flows, extreme temperatures including heat waves and cold waves, droughts, wildfires, thunderstorms, lightning, hail, tornadoes, tropical storms (e.g. hurricanes), floods, fog, freezing rain and ice storms in Canada. Decision makers in the public health and emergency management fields require such information to gauge future risks to health, prioritize risk management activities among other issues of concern, and develop needed adaptive options.

Engagement of stakeholders and partners was crucial in this Assessment. It contributed to (1) identifying and validating the assessment approach, (2) scoping out priority health issues and regions for examination, (3) obtaining key information needs of health sector decision makers, (4) providing advice on communicating results of this Assessment, and (5) enlisting needed expertise and research assistance when required. For example, as a result of consultative workshops, it was determined that decision makers need key information on the status of existing risk management activities and on the effectiveness of those activities for each health issue or region examined. Such analysis was included in a number of the chapters, particularly Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada.

Furthermore, analysis in this Assessment enlisted cooperation from a broad range of experts to best characterize and assess health impacts and vulnerabilities associated with climate change. Collaboration with climate modellers at Environment Canada was instrumental for projecting the potential impacts of possible future climate warming on air quality, and climate modelling input from officials with the Ouranos Consortium allowed authors of Chapter 6, Health Impacts of Climate Change in Quebec, to project the number of heat-related deaths from climate change for a number of communities in that province. In addition, integration of information from the Canadian Disaster Database in Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, benefited from expert advice and review by officials in Public Safety and Emergency Preparedness Canada.

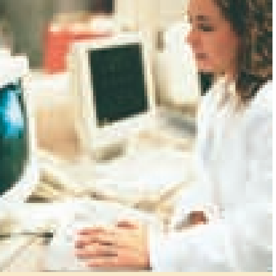
Experience with the application of key methods for assessing climate change-related health risks and vulnerabilities suggests that future assessments would benefit from:

- development of other models and tools to allow additional non-climate drivers of health impacts to be considered through cross-sectoral integrated assessment;
- development of climate scenarios, general circulation models and regional downscaling techniques that provide finer spatial and temporal resolutions to provide needed information on the changes in the frequency and intensity of extreme weather events (rather than just mean values) and inform regional or local adaptation initiatives. Data and model constraints, and limitations in temporal and spatial resolution of climate scenarios mean that examination of the future burden of disease could not be estimated for all health issues and for each region under investigation;



- development of quantitative indices of vulnerability and adaptive capacity to compare ability to cope with climate change and health risks at the country, regional and local levels; and
- more extensive data on (1) illnesses and deaths from key climate change health concerns (e.g. deaths related to extreme temperatures), (2) the role of health services in mitigating natural hazards or in aiding the victims of natural disasters, (3) the effectiveness of current adaptations, and (4) future socio-demographic trends with which to gauge vulnerability.

The experience of conducting climate change and health assessments in the North and in the province of Quebec provides insights and best practices for assessments at the regional scale that can be applied to future studies. For example, such initiatives benefit greatly from a comprehensive review of the current health and socio-demographic status of the relevant populations. They are also aided by investigations of perceptions and observations of local-level decision makers and stakeholders who have an important role to play in future adaptation development processes. Based upon investigations of the effectiveness and/or costs of adaptation measures, such information will be critical for the identification of priority actions that should be adopted to prepare for all, or the most likely, health impacts expected under climate change.



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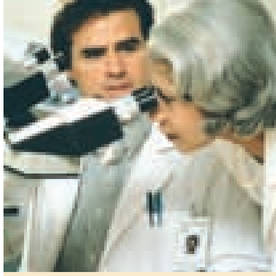

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Chapter 3

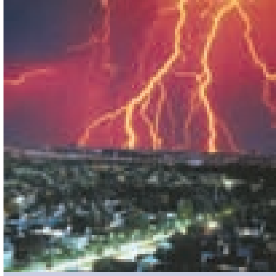
Vulnerabilities to Natural Hazards and Extreme Weather

Peter Berry

Gordon McBean

Jacinthe Séguin

Contributors:
Andrew Hallak
Michel Jean
Justine Klaver-Kibria
Paul Kovacs
Dieter Riedel
Jinhui Zhao



Chapter 3

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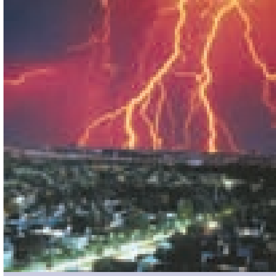
Chapter 3



3.1 INTRODUCTION

This chapter examines how natural hazards affect the health of Canadians, how climate change is influencing natural hazards and related risks across the country, and what conditions determine individual and community vulnerability to these risks. From the perspective of the emergency management community, three factors combine to create a hazard: the probability of occurrence of events that can impact a community, the vulnerability of the population to such impacts, and the resources of the community to cope with those impacts. All three factors are examined in this order in this chapter, leading to conclusions about the preparedness of Canadians, knowledge gaps and needed policies and programs. Because climate change does not influence all types of natural hazards (e.g. earthquakes), the scope of this chapter focusses on weather and weather-related events. However, some data and statistics quoted in the chapter include information on all hazards and natural disasters.

Generally, weather and weather-related events relate to conditions defined in terms of heat and cold, wet and dry, and wind and pressure conditions, which often come in combinations such as snow and ice storms, and floods and droughts. These weather conditions then generate related hazards such as landslides, wildfires, avalanches, storm surges, and melting ice and permafrost (some of which may also be considered geological hazards). A hazard is the potential for a negative interaction between extreme events (of a natural or technological origin) and the vulnerable parts of the population. Numerous scientific studies have established that changes in temperature, barometric pressure, humidity, and other determinants of weather and climate can affect human health and well-being.

Photo Credits:
Canada Centre for Remote Sensing, NRCan

Landslide (Saguenay, 1996)

While many natural hazards have the potential to affect human health, they become disasters when certain vulnerabilities are present (Etkin et al., 2004). Around the world, the impacts of natural disasters have been increasing dramatically; the number of natural disaster events was 10 per year from 1900 to 1940, 65 per year in the 1960s, 280 per year in the 1980s, and 470 per year since the beginning of this century (Emergency Disasters Database, 2007). Although part of the reason for this increase may be better systems for reporting disasters, this does not explain the observed increase in the number of extreme weather events. The greater frequency of these events and the higher vulnerability of human systems to them are important for explaining this observed increase in the number of disasters.

A disaster is defined as "a serious disruption of the functioning of a community or a society causing wide-spread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources" (United Nations International Strategy for Disaster Reduction (UN/ISDR), 2004).

In Canada, people living in all parts of the country can be affected by natural hazards, and should be concerned about how their exposure to these hazards may be changing over time because of climate change. Public Safety Canada (PSC) (formerly Public Safety and Emergency Preparedness Canada) maintains a database of Canadian disasters dating from 1900 to the present. Information in this database is useful for determining the current frequency and longer-term trends of events of a certain size, based upon their

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costs and related injuries and fatalities. However, these records do not provide information on the range of health impacts that are caused or exacerbated by natural hazards, nor do they include estimates of health sector costs associated with these events. Instead, it is through detailed examples provided by case studies that researchers begin to understand the scope of health impacts. This chapter highlights the health impacts and the economic costs associated with a range of events drawn from the PSEPC database and Canadian case studies.

In the 1990s, natural disasters caused 170 deaths and 1000 injuries, and affected over 700,000 Canadians. Those people affected were evacuated from their homes, lost power, or were made homeless. The largest number of these resulted from the 1998 Ice Storm that affected eastern Canada (PSEPC, 2005a). Although mortality in Canada attributed to natural disasters has decreased in the past several decades, injuries and the number of people affected have risen.

At the global scale, weather and weather-related events together make up most of all natural disaster events, with floods (33%), storms (23%, which includes hurricanes, typhoons, tornadoes and mid-latitude winter storms), and droughts (15%) as the major contributors. Most avalanches and many landslides are also weather-related. The *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC) confirmed that meteorological and hydrological events that can impact human health are expected to increase in the future, irrespective of near-term efforts to reduce greenhouse gas (GHG) emissions (IPCC, 2007a). Risks to Canadians and their communities will therefore increase, and will require concerted efforts to plan for, and where possible, reduce the impacts on health.

Although the characteristics of specific weather events are important for assessing the risks that individuals and communities face, existing social and economic conditions and emergency management strategies for coping with an event are also critical in determining the scope of the impacts. Canadian experience has shown that highly resilient communities prepare for and respond more effectively to disasters, and that these communities are better able to protect the most vulnerable people in the population (Federal/Provincial/Territorial (F/P/T) Network for Emergency Preparedness and Response, 2004).

3.2 METHODS AND LIMITATIONS

This chapter reviews Canadian and international literature to assess the impacts of natural hazards on health, the geographic scope of such hazards in this country and the special characteristics that make Canadians vulnerable to impacts related to climate change. Using case studies and examples, current adaptations to protect individuals, communities and property are highlighted. To support future adaptation efforts, current knowledge gaps are identified, and the actions needed to increase health risk management capability and the resilience of Canadians are examined.

The focus of the chapter was guided by recommendations arising from consultations and workshops organized by the Institute for Catastrophic Loss Reduction (ICLR) and Health Canada, respectively. Participants included emergency sector experts and practitioners from academia; municipal, provincial and federal governments; and non-governmental organizations. In addition, a workshop was held in 2003 to identify key natural hazards to be examined in this chapter. Floods, heat waves, cold waves, wildfires, convective storms, and snow and ice storms were highlighted as priority hazards in terms of health impacts for Canadians. Workshop participants also identified the need to examine psychosocial impacts of natural hazards and disasters, the effectiveness of risk management activities to protect people from current and future risks, and the adaptive capacity of institutions and individuals (Health Canada, 2003).

Photo Credits: Communications New Brunswick, Govt. New Brunswick

Man setting sandbags during flooding

Baseline information on the spatial distribution of natural hazards and on the occurrence of extreme weather events for all regions of Canada is presented throughout the chapter, along with evidence of health impacts from case studies. The chapter has drawn its analysis from original data sources and reviews of published and grey literature. The literature review targeted both peer-reviewed scientific publications, and a variety of technical and government reports. Search terms included global warming, climate change, cold, heat, natural hazards, storms, floods, drought, wildfires, disasters and other terms related to natural hazards and disasters in Canada that might be influenced by climate and weather. Particularly useful sources included maps from the Atlas of Canada, published by Natural Resources Canada (NRCan), and information from Public Safety Canada's searchable Canadian Disaster Database. This database summarizes information on past weather-related disasters in Canada that are defined as historically significant events, or those in which either:

- 10 or more people were killed;
- 100 or more people were affected, injured, evacuated or became homeless;

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- an official appeal was issued for national or international assistance; or
- damage to or interruption of community functions was so great that it prevented recovery of the community on its own.

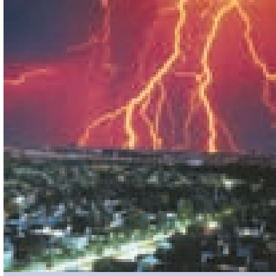
The database is continually updated and, at present, it covers the years 1900 to 2005. Unless otherwise indicated, most of the statistics cited in this chapter have been obtained from this source. Another important source of information was the Meteorological Service of Canada, which is the principal source of weather and climate information for Canadians. It provides forecasts, advisories, maps and other information related to weather and climate (Environment Canada, 2007a).

Limitations in time and space for this project resulted in an uneven coverage of topics, geographic regions and events that have been illustrated by selected graphics, statistics and case studies. More comprehensive information can be found in the many references cited herein. More detailed information on some hazards relevant to the health of Canadians living in Quebec and the North can be found in Chapter 6, Health Impacts of Climate Change in Quebec, and Chapter 7, Health Impacts of Climate Change in Canada's North, respectively. As well, Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada, more fully addresses the problems of how to anticipate, cope with, and prevent natural disasters related to climate change.

As well, there are few studies on long-term health impacts and the role of health services in the recovery process following a natural disaster. While recovery processes would be expected to play a role in influencing the resilience of communities that have had to cope with natural disasters, few Canadian studies have examined the factors that could have led to successful recoveries. In some rare cases, journalists and photographers have vivid on-the-spot accounts of the experiences of victims and emergency personnel during and soon after a major disaster (Anderson et al., 2003). But as yet, there are few comprehensive accounts of whether and to what extent neighbourhoods or communities have recovered from such disasters. The August 2003 wildfire disaster in the southern interior of British Columbia seems to be the only one in which health authorities commissioned a report that is easily accessible on the performance of emergency medical services and related matters (Lynch, 2004).

Photo Credits: British Columbia Ministry of Forests and Range

Wildfires in British Columbia, 2003



3.3 NATURAL HAZARDS AND HEALTH IMPACTS IN CANADA

3.3.1 Overview

Each region of Canada has unique susceptibilities to extreme weather, and to weather-related natural hazards; these are greatly influenced by specific geographic and geologic features of the region. Examples include the so-called storm paths and “tornado alleys” along the Great Lakes-St. Lawrence River corridor, the unstable hillsides and river valleys in mountain regions that are susceptible to rock-, mud- or landslides, and severe droughts in the southern Prairies that can lead to dust storms and wildfires. Some coastal regions are vulnerable to storm surges and the decrease in winter sea ice which protects the coast from erosion. In addition, many inland river basins are also subject to flooding and erosion.

There is a lack of reliable and comprehensive data on disasters and weather-related events in Canada (Etkin et al., 2004). The Canadian Disaster Database is the most comprehensive database of Canadian information on natural hazards. However, it records only events and related injuries, deaths and economic losses that meet the defined disaster criteria; many weather-related hazardous events of concern reviewed in this chapter (e.g. fog occurrences, thunder and rain storms, heat waves) are not typically recorded in this database. Consequently, statistics from this database underestimate both the total number of occurrences of weather events as well as the scope of their impacts. Despite these limitations, according to records dating back to 1900, there is an increasing trend in the occurrence of natural disasters and associated costs, with considerable year-to-year variability. The total number of Canadians affected by natural disasters increased from 79,066 between 1984 and 1993, to 578,238 between 1994 and 2003 (Health Canada, 2005a). Another database, using different inclusion criteria than the Canadian Disaster Database, also showed that 51% of all Canadian disasters were weather-related (Jones, 2003).

Figure 3.1 A century of natural disasters in Canada

	1900–1960s	1970s	1980s	1990s	2000–2002
Estimated number of disasters	160	92	114	151	29
Estimated number of deaths*	3,010	114	283	179	18
Estimated number of affected*, †	162,462	25,477	50,285	712,625	154
Estimated direct damage costs (CAN$)‡, §	4,882 billion	9,712 billion	17,617 billion	13,710 billion	0.203 billion

Notes: Data compiled using natural disaster information about meteorological events.

* Health data were either not available or could not be confirmed for a number of disasters.

† The number of people affected was calculated using the number of people injured plus the number of people evacuated during a disaster event.

‡ Disaster damages are based on 1999 Canadian dollars for those disasters occurring between 1915 and 2002. Total amount of disaster damages is based on cost data for 76 of 160 disasters occurring between 1900 and 1969, and for 324 of 388 disasters occurring between 1970 and 2002.

§ Damage estimates are conservative and include only direct costs, excluding uninsured and indirect costs, such as hospitalization costs, which are difficult to quantify.

Source: Data from PSEPC, 2005a.

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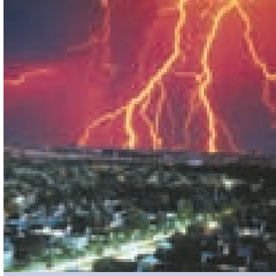
The human health implications of climate change across the globe have been examined under the combined sponsorship of the World Health Organization (WHO), the World Meteorological Association (WMO) and the United Nations Environment Programme (UNEP) (McMichael et al., 1996; McMichael, 2003). They concluded that weather-related disasters might increase in frequency and intensity as a result of climate change, but noted that the secondary effects and delayed consequences of such events are poorly documented and reported.

Weather-related disasters pose a threat to human life, health and well-being in a variety of ways (Health Canada, 2003; ICLR, 2003) (Table 3.1). Some events result in more direct and more immediate impacts than do others. For example, flooding, drought, severe storms and other weather-related natural hazards can damage health by leading to an increased risk of injury, illness, stress-related disorders and death (Hales et al., 2003). Other impacts on health are less direct and longer-term, such as mould in buildings as the result of flooding, which can have resulting impacts well after the waters have receded (Solomon et al., 2006). Still others may not be felt for weeks or months and may last for years, such as a drought causing economic hardship with a resulting strain on health.

Although dramatic events like tornadoes and floods receive most media attention, evidence suggests that changing temperature and other weather variables also affect human health. Weather variables are associated with hospital admissions for respiratory diseases over certain periods (Makie et al., 2002; Hajat et al., 2004), and relationships between weather variables and hospital presentations for asthma and asthmatic syndromes have been examined (Celenza et al., 1996; Harju et al., 1997; Ehara et al., 2000).

Table 3.1 Key weather-related natural hazards in Canada and their associated health impacts

Extreme Weather Event	Examples: Health Impact Pathway(s)	Examples: Potential Health Effects	Populations at Higher Risk
Extreme heat	• Body temperatures are elevated beyond normal range • Increased growth and abundance of disease-causing organisms and/or vectors • Air quality is negatively affected	• Dehydration • Heat-related illnesses (heat stroke, fainting, heat cramps, heat rash) • Existing medical problems made worse, such as asthma and allergies • Physical and mental stress • Respiratory and cardiovascular disorders • Food-borne diseases • Vector-borne infectious diseases	• Young children • Seniors (especially those who are bedridden, unable to care for themselves or socially isolated) • Chronically ill individuals • People with compromised health status • People living in areas with poor air quality • People working or exercising outdoors • People without access to air conditioning • People on certain medications
Extreme cold	• Body temperature is reduced below normal range	• Frostbite • Hypothermia • Death • Increased risk of injury due to accidents (car, slipping on ice, shovelling snow)	• People without shelter • People who play or work outdoors • Children • Seniors



Extreme Weather Event	Examples: Health Impact Pathway(s)	Examples: Potential Health Effects	Populations at Higher Risk
Extreme rain or snowfall	• Flooding and its after-effects (e.g. poor indoor air quality from growth of moulds) • Increase in populations of mosquitoes and other disease carriers • Contamination of drinking water by chemicals or wastes in surface runoff • Failure of essential infrastructure (e.g. sewers, water treatment facilities) • Algal blooms and other changes in aquatic ecology	• Physical injury, shock and trauma • Death by drowning • Respiratory illnesses • Outbreaks of vector-borne infectious diseases • Outbreaks of crytosporidiosis, giardiasis, amoebiasis, typhoid and other water-borne infections	• Children • Seniors • People living along coasts or waterways • People with chronic illnesses • People with compromised health status • People with impaired immune systems • People with inadequate or no housing
Extreme drought	• Water shortages • Crop failures • Reduced water quality • Wildfires • Air pollution due to dust and smoke	• Respiratory illnesses from dust and smoke from fires • Outbreaks of water-borne illness due to increased concentration of contaminants • Hunger, malnutrition and associated stress disorders due to crop failures and economic hardship • Injury or death (in extreme cases) • Stress from loss of property, livelihood, displacement and community disruption	• People living in drought-prone areas • Agriculturally dependent communities • People without insurance • People without resources (e.g. financial and social)
Severe storms	• High winds • High waves and storm surges • Flooding • Property damage • Damage to essential infrastructure (e.g. power lines, hospitals, water treatment plants) • Damage to personal property • Increased risk of automobile accidents	• Physical injuries or death from falls, collapsing buildings, windblown debris, house fires, motor vehicle accidents, etc. (especially head injuries, fractures and lacerations) • Hypothermia • Electrocution • Food-borne disease • Respiratory illness and asthma due to pollen and spores • Drowning • Stress disorders from loss of loved ones, property and livelihoods	• People living in storm-prone areas • People living in low-lying coastal areas or in regions prone to flooding • People living in areas where environmental degradation has created hazardous conditions

Source: Adapted from Health Canada, 2005a, 2005b.

Some population groups are more vulnerable to natural hazards than others.[1] The degree to which people are vulnerable to these hazards varies significantly across the country and is influenced by, among other things, where people live, their age, the socio-economic conditions of family and community, and institutional services and infrastructures. Research into the impacts of natural hazards on health in Canada is in its infancy. Attributing illnesses to natural hazards is difficult, and requires the application of appropriate methodologies and analytical approaches to draw causal relationships. However, lessons

1 See section 3.5, Individual and Community Vulnerability, for a discussion of vulnerable populations.

can be drawn from analysis of recent events within Canada and internationally to profile hazards, vulnerable populations, and ways to reduce the impacts on individuals and communities.

The sections that follow review the many weather-related hazards in Canada, organized according to their importance in terms of the number of Canadians exposed to the natural hazard, and the known health impacts on the Canadian population.

3.3.2 Extreme Temperatures

Each year, large regions of Canada experience periods of very hot (above 30°C) and very cold weather (below -15°C) that can have both direct and indirect impacts on human health and well-being. Across Canada, average temperatures have increased by 1.2°C between 1945 and 2006, and this trend is expected to continue (Environment Canada, 2007d). As the mean temperature rises, the frequency of occurrence of extreme events increases (IPCC, 2007c). Therefore, temperatures above some threshold, such as 30°C, will become more common and temperatures below a cold threshold will become less common.

Temperature patterns vary significantly across the country. Communities in some regions (e.g. southern Alberta) can experience sudden winter temperature increases of up to 27°C in a few minutes, caused by warm chinook winds (Nkemdirim, 2007). In the high Arctic, temperatures may range from -55 to +22°C over the course of a year (Environment Canada, 2005e). Temperatures in urban and rural communities tend to differ because of the "urban heat-island effect" in city core areas (Oke, 1997; Lo and Quattrochi, 2003; Clean Air Partnership (CAP), 2004). This makes for milder winter temperatures in large urban areas, but higher summer temperatures that can exacerbate the effects of heat waves.

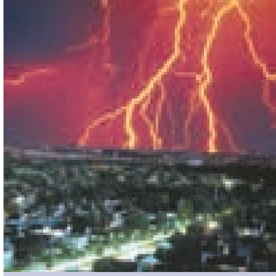
Humans and animals can acclimatize to a fairly narrow range of temperatures (their thermoneutral or comfort zone), but can suffer from excessive heat loss (hypothermia) or heat gain (hyperthermia) at extreme temperatures, which can result in illness or death (Campbell and Norman, 2000).

3.3.2.1 Heat waves

Heat waves are periods of abnormally and uncomfortably hot temperature lasting from several days to several weeks, and may be accompanied by high humidity and air pollution (American Meteorological Society, 2000). Canadian communities, especially in the Windsor-to-Quebec corridor along Lakes Erie and Ontario and the St. Lawrence River, portions of British Columbia, the Prairie region and even the northern territories may experience spells of uncomfortably or stressfully hot weather (Environment Canada, 1999; Smoyer-Tomic et al., 2003).

According to the Canadian Disaster Database, between 1900 and 2005, five major heat waves causing multiple deaths occurred in Canada. In 1936, the worst of these extended across much of Canada with temperatures ranging from 32 to 44°C, resulting in close to 1,180 deaths, mostly of seniors or infants. About 400 of the victims drowned while trying to escape the heat by cooling off in rivers, lakes or the sea (Environment Canada, 2005a). Four other severe heat waves occurred in the years 1912, 1953, 1963 and 1988 in the Prairie region or in southeastern Canada; together these resulted in at least 23 deaths and 186 illnesses requiring medical attention (PSEPC, 2005a).

Prolonged exposure to a sudden increase in environmental temperatures above 30°C (i.e. heat waves), especially when accompanied by high humidity and severe air pollution, can be especially dangerous for infants, seniors and for people in frail health, particularly those taking certain medications (Havenith, 2005). This danger is heightened early in the year when people have not yet had an opportunity to acclimatize to severe heat (Havenith, 2005). The health problems associated with extreme heat increase with longer periods of high temperatures (Toronto Public



Health, 2007). Heat-related illnesses include skin rashes, cramps, unconsciousness, exhaustion and heat stroke. The special vulnerability of economically disadvantaged people and of seniors in urban environments to heat stress was particularly evident in the disastrous heat wave of August 2003 in Europe, when an estimated 33 000 excess deaths occurred across western Europe, mostly among the very old (Kosatsky, 2005). Heat illnesses are preventable by limiting exposure to hot weather to a short period of time and by accessing cool areas to lower body temperature. Drinking plenty of liquids to maintain adequate body fluids and abstaining from alcoholic or caffeinated beverages also helps to prevent heat-related illnesses.

A study of four Canadian cities showed that from 1954 to 2000, about 120 people died each year due to heat-related causes in Toronto, 121 in Montreal, 41 in Ottawa, and 37 in Windsor (Cheng et al., 2005). In Toronto between 1980 and 1996, temperature values of 30° to 35°C (based on a humidex value) were accompanied by increased mortality for all ages, especially among those over the age of 64. In 2005, there were six heat-related deaths among residents of rooming houses and boarding houses in that city. Persons of low socio-economic status, including homeless persons, are considered to be at high risk of heat-related illness or death (Smoyer-Tomic and Rainham, 2001; McKeown, 2006).

Smoyer-Tomic et al. (2003) reviewed heat wave hazards and their health impacts across Canada, and found that the highest summer temperatures and most frequent heat waves occurred in the Prairies, southern Ontario and the St. Lawrence River valley, including Montreal. They also judged Montreal residents to be particularly vulnerable to extreme heat because the city has a high proportion of older high-density housing without air conditioning. In southern Ontario, Smoyer et al. (2000) found the population in the Windsor-to-Toronto corridor, especially those older than 64 years, to be at greatest risk of heat-related mortality because of frequent hot and humid summer weather conditions. At temperatures above 32°C, heat-related deaths were most frequent in Toronto, London and Hamilton. However, even urban areas located next to mountains and large bodies of water (e.g. Vancouver and its suburbs) can act as urban heat islands (Roth et al., 1989).

Urban heat island research in Canada has focussed on three principal metropolitan regions: Montreal, Toronto and Vancouver. As of 2007, active research programs are ongoing in each of these three cities. In Montreal and Vancouver, research is being undertaken by the Environmental Prediction in Canadian Cities (EPiCC) network (EPiCC, n.d.). Its goal is to improve the safety, health and well-being of Canadians through a better understanding of urban climates.

The Clean Air Partnership, a Toronto-based non-governmental organization, has maintained an ongoing urban heat island research program since 2002 (CAP, 2007). It has been responsible for the “Cool Toronto” initiative, which includes the production of a number of public education products (e.g. website, fact sheets).

More recently, the Canadian Centre for Remote Sensing (Natural Resources Canada) and the Clean Air Partnership have begun a multi-year research project called the Assessment of Urban Heat Island Impacts in the Greater Toronto Area Region. The research project involves detailed data collection and modelling exercises to assess the microclimate associated with various land uses and building types.

3.3.2.2 Cold waves

Cold waves are unusually large and rapid drops in temperature that can be accompanied by high winds and heavy snowfalls, and are usually followed by prolonged periods of intensely cold weather. They are a common occurrence in some regions of Canada, although all parts of the country can be affected. In the past century (from 1900 to 2005), nine have reached the scale of a recorded disaster by causing a total of 35 deaths (PSEPC, 2005a).

Mortality statistics, however, do not accurately describe the full health impact of cold waves. For those who are exposed to bitterly cold air, injuries such as frostbite and hypothermia may occur. The risk of cold injuries is increased at high wind speeds, which accelerate heat loss from the body. Therefore, Environment Canada issues weather warnings for cold waves, high winds and wind chill (Environment Canada, 2003e, 2005b). During cold alerts, vulnerable groups are usually people living in sub-standard housing, those engaged in outdoor occupations, alcoholics, the homeless and seniors (Ranhoff, 2000).

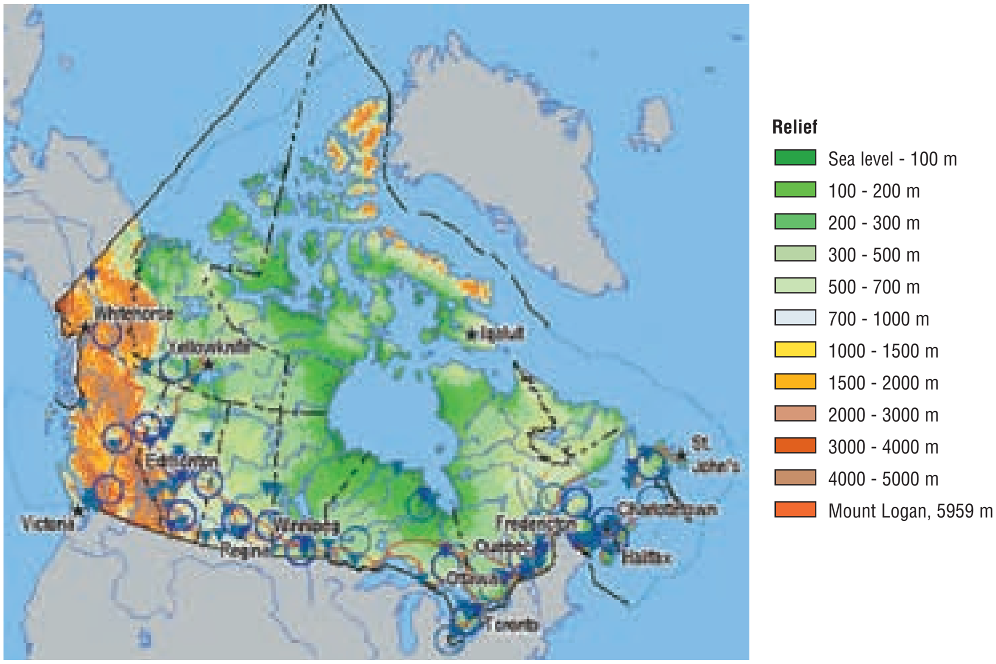
Cold-induced stress can lead to viral and bacterial infections and contribute to a pronounced peak in mortality in Canada during the cold season (Trudeau, 1997). In a study of temperature-related injuries in Montreal, most of the injuries and deaths due to extreme temperatures were caused by cold (Koutsavlis and Kosatsky, 2003). The principal determinants of cold-related injury include male gender, alcohol intoxication, psychiatric illness, older age, and homelessness. The Montreal study is unique within the Canadian context, given the lack of data on determinants of environmental-temperature injury in other cities (Koutsavlis and Kosatsky, 2003).

3.3.3 Floods

Floods are defined as water flowing temporarily over normally dry land, due to a variety of causes such as excessive rain during hurricanes or thunderstorms, rapid melting of snow or ice, blocked watercourses, storm surges in coastal areas, land subsidence or the failure of dams. Large parts of Canada's inhabited areas are susceptible to flooding because of excessive precipitation and surface run-off, rapid melting of snow and ice in the spring, and other causes identified in the Atlas of Canada (Etkin et al., 2004).

Floods have been the most commonly reported disasters in Canada (Tudor, 1997). From 1900 to 2005, at least 170 major floods occurred in Canada (PSEPC, 2005a), many of these in southern Ontario, southern Quebec and New Brunswick, and in Manitoba (Figure 3.2). They were frequently caused by spring snowmelt run-off combined with rain, and ice jams on rivers (Geological Survey of Canada, 2006; Atlas of Canada, 2007a).

Figure 3.2 Occurrence of major floods in Canada during the 20th century



Note: Triangles indicate floods with local effects and circles represent floods with regional effects.

Source: Atlas of Canada, 2007a.

The number of flood disasters along Canadian rivers seems to be on the rise, with 70% of floods of the past century occurring after 1959. This may be due partly to more intense precipitation events, but also to population growth that has led to the expansion of settlements in vulnerable flood plains. Better reporting during the last few decades may also have led to an increase in the number of documented natural disasters, including floods (Brooks, 2006).

There are several major categories of floods, which have different causes. The first of these are "flash floods" caused by local storms with heavy rainfalls that quickly saturate the earth, leading to major run-off and unusually high peak flows in the rivers, especially in mountain areas. They usually occur along quickly flowing rivers in relatively narrow valleys, and can happen so quickly that there is little time to prepare for them. Flash floods tend to be of relatively short duration, and occur mostly during the peak thunderstorm season in the summer. The fast-flowing water can cause massive erosion, undermining roads, dams, dykes and bridges. Examples are the 1996 Saguenay and 2003 Bois Francs floods in Quebec (NRCan, 2005a; Couture, 2006). In cities, flash floods can cause sewer backups into buildings, flooding of underpasses, tunnels or below-grade expressways, and may cut off electricity supplied by vulnerable power lines or substations. This happened in July 1987 in and around Montreal after thunderstorms dropped more than 100 mm of rain. As a result, at least 40,000 homes and one health care centre were flooded, about 350,000 homes lost electricity, and the flooding of a major expressway and other roads caused over 400 cars to stall and to be abandoned, with many of their occupants requiring rescue by emergency services (Environment Canada, 2005d).

Photo Credits: Communications New Brunswick, Govt. New Brunswick

Flooding in New Brunswick, 2005

The second kind of flood results from a quick thaw following a winter with unusually deep snow and ice cover. This flooding usually takes place during the spring along large, flat river basins with gentle slopes; this results in large peak flows of slowly moving water. The run-off meltwater inundates wide areas that tend to remain flooded for a long time because of slow water drainage. Examples are the rivers of the central Prairie region that flow through a rather flat landscape with poor drainage, such as the Red River and Assiniboine River basin of North Dakota, Minnesota and Manitoba (Brooks et al., 2001; Environment Canada, 2005c). Similar conditions prevail along the Saint John River valley in New Brunswick, the upper St. Lawrence River basin, and the Fraser River and Mackenzie River deltas (Environment Canada, 2004b).

The third kind of flood is caused by storm surges, when strong winds that cross open water push large waves against shorelines. Some shore areas around the Great Lakes, as well as coastal areas of Nova Scotia, Prince Edward Island, New Brunswick and Newfoundland and Labrador are vulnerable to storm surges (Environment Canada, 2004b).

The implications of climate change for coastal regions in Canada include accelerated sea level rise, warmer ground temperatures in high latitudes (therefore enhanced melting of permafrost in the North), reduced sea ice extent in the Arctic and mid-latitude seas such as the Gulf of St. Lawrence (therefore increased wave energy) and changes in large-scale atmospheric circulation patterns causing an increase in storm frequency and severity. All of these impacts can increase the risks of flooding in coastal regions.

Table 3.2 provides information on the health impacts of floods. The existing literature suggests that the less tangible, psychosocial effects can be the most damaging (Menne et al., 1999; Hutton, 2005). Studies in Europe and the United States (U.S.) establish a correlation between flooding and subsequent increases in a range of common mental disorders (e.g. anxiety, depression, post-traumatic stress disorder) that can last, in some instances, for years (WHO, 2002; Hutton, 2005). It is hypothesized that certain vulnerable groups, such as children and low-income families, are more susceptible to such long-term impacts (WHO, 2002).

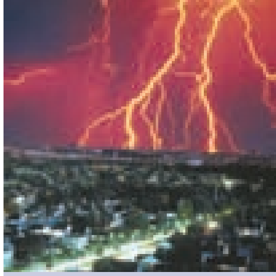


Table 3.2 Impacts of floods on human health

Direct Effects

Causes	Possible Health Concerns
Stream flow velocity, topographic land features, absence of warning, rapid speed of flood onset, deep floodwaters, landslides, risk behaviour, fast-flowing waters carrying boulders and fallen trees	Drowning, injuries
Contact with water	Respiratory diseases, shock, hypothermia, cardiac arrest
Contact with polluted waters	Wound infections, dermatitis, conjunctivitis, gastrointestinal illnesses, ear, nose, and throat infections, water-borne diseases
Increase of physical and emotional stress	Increased susceptibility to psychosocial disturbances and cardiovascular incidents

Indirect Effects

Causes	Possible Health Concerns
Damage to water supply, sewage and sewage disposal damage, insufficient supply of drinking water, insufficient supply of water for washing	Water-borne infections (enterogenic *Escherichia coli, Shigella,* hepatitis A, leptospirosis, giardiasis, campylobacteriosis), dermatitis, conjunctivitis
Disruption of transportation systems	Food shortage, disruption of emergency response
Underground pipe disruption, dislodgement of storage tanks, overflow of toxic-waste sites, release of chemicals, rupture of gasoline storage tanks leading to fires	Acute or chronic chemical pollution
Standing water, heavy rainfall, expanded range of vector habitats	Vector-borne diseases
Rodent migration	Rodent-borne diseases
Disruption of social networks; loss of property, jobs, and family members and friends	Psychosocial disturbances
Clean-up activities following floods	Electrocutions, injuries, lacerations, skin punctures
Destruction of primary food products	Food shortage
Damage to health services, disruption of 'normal' health services activities	Decrease of "normal" health care services, insufficient access to medical care

Source: Menne et al., 1999.

Despite the frequent occurrence of floods in Canada, very few deaths and relatively few injuries have occurred: fewer than one recorded death per year during this past century (PSEPC, 2007). This low number may be because, for most large floods, the water rose gradually, allowing for preventive measures and safe evacuations. Several large-scale floods since 1900 led to the evacuation of more than 200,000 people; almost half of these were due to the Red River flood in Winnipeg in 1950 (PSEPC, 2005a). The psychosocial effects of flooding can be substantial. Although commercial insurance coverage is available, the recovery of affected families and individuals can be potentially arduous because residential flood insurance does not exist in Canada (Etkin et al., 2004).

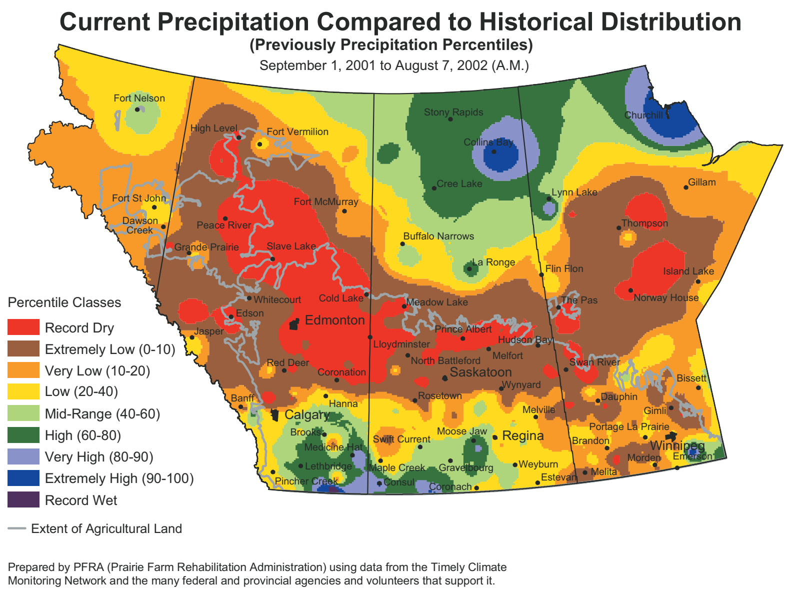
The literature on the health impacts of floods is limited in scope due to the lack of relevant data and indicators, as well as tools to assess health risks and vulnerability (Hutton, 2005). The assessment of the medium- to long-term impacts of flooding, especially the psychological impacts on human health and well-being, is an area in significant need of greater research (Hutton, 2005).

Chapter 3

3.3.4 Droughts

A drought is a temporary period of insufficient precipitation (mostly rain or snow), resulting in inadequate surface and subsurface water supplies for ecosystem and human needs. Droughts are most common in the Prairie provinces where long-term average precipitation is already quite low, amounting to about 500 to 900 mm annually (King, 2007). Between 1950 and 2000, Canada experienced at least 37 major droughts, about two thirds of which occurred in the Prairie provinces (PSEPC, 2005a). The most recent severe drought to affect Canada occurred in 2001–2002, and extended over most of southern Canada, although the most affected regions were Alberta and Saskatchewan. It caused large crop and livestock production losses in other regions as well (Wheaton et al., 2005; Agriculture and Agri-Food Canada, 2006, 2007).

Figure 3.3 Extent of the record drought in Western Canada, 2001–2002



Note: Areas shaded in yellow, orange, brown and red indicate increasing levels of precipitation deficits.

Source: Agriculture and Agri-Food Canada, 2006.

While no deaths have been directly attributed to drought in Canada, the effects of economic damage and dust may have contributed to excess morbidity and mortality. Droughts particularly affect farmers and ranchers through greatly reduced crop yields and livestock production, with resulting economic losses (Herrington et al., 1997; Wheaton et al., 2005). The 2001–2002 drought led to the loss of more than 41,000 jobs, economic losses amounted to \$3.2 billion, and net farm income in several provinces was zero or negative for the first time in 25 years (Wheaton et al., 2005). Some of the economic losses of the drought in the Prairie region were partly offset by crop insurance payments, which amounted to about \$2.5 billion for Alberta and Saskatchewan (Wheaton et al., 2005).

Stress related to financial pressures resulting from droughts, combined with the effects of an environment degraded by dust storms and wildfire smoke, can have many adverse health impacts, such as respiratory illnesses, exhaustion, depression or even suicide (Walker et al., 1986; Deary et al., 1997; Malmberg et al., 1997; Smoyer-Tomic et al., 2004; Soskolne et al., 2004). Surface-water evaporation during droughts lowers water levels and causes suspended and dissolved matter to become more concentrated. This may stimulate the growth of toxic algae (U.S. Environmental Protection Agency (U.S. EPA), 1995). During droughts, some communities have to curtail their water use and hydroelectric power production is reduced, as are recreational and tourism-related activities.

Chapter 3

3.3.5 Wildfires

Wildfires and forest fires are closely associated with droughts and thunderstorms. Droughts favour the accumulation of dry plant materials that burn easily and can serve as starter material for wildfires. Wildfires may occur in grass, peat, shrub and forest regions, but they tend to become largest and most persistent in forests, where there is abundant fuel. Lightning strikes associated with thunderstorms often ignite the dry material; they cause 35% of all forest fires (NRCan, 2004b, 2004c). On average each year, there are more than 8,000 forest fires in Canada that burn 0.7 to 7.6 million hectares (Figure 3.4). While the vast majority of wildfires occur far from human settlements, an increasing number occur at the "wildland-urban interface," as community expansion, cottages, tourist camps and other economic development initiatives encroach upon forests or lands with abundant shrubs, trees and other vegetation.

In British Columbia alone, several hundred thousand people, as well as thousands of private and business properties, are at risk from such fires, which will likely become more frequent (Bothwell, 2004; Filmon et al., 2004; Lurie, 2004). The same problem likely also exists in other parts of Canada, but has not yet been assessed.

Figure 3.4 Occurrence of forest fires in Canada, 2005

Note: orange dots represent reported forest fires.

Source: Atlas of Canada, 2008.

In Canada, 52 nationally significant forest fires occurred in all provinces and territories between 1900 and 2005; most occurred in Quebec (8), Ontario (16), Saskatchewan (7) and British Columbia (6) (PSEPC, 2005a). Since 1900, major forest fires have forced the evacuation of at least 44 communities and more than 155,000 residents, and caused the deaths of at least 366 people (NRCan, 2004b; PSEPC, 2005a). Most of these deaths occurred in the first half of the 20th century, before the development of modern communications networks and airborne forest fire-fighting teams and equipment, such as water bombers.

For those directly exposed to wildfires, the health impacts can be acute and may include hyperthermia and dehydration, eye irritation and respiratory irritation leading to bronchitis caused by exposure to smoke and ash. As well, physical and mental exhaustion, stress-related hypertension and post-traumatic stress syndrome may be experienced, especially by fire fighters and other emergency personnel. Some of these impacts may also be experienced by people who have lost their homes to fire and by those who are evacuated for safety reasons (Mackay, 2003).

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Photo Credits: British Columbia Ministry of Forests and Range

Lillooet, British Columbia, 2004

Apart from the immediate deaths, injuries and loss of property and community services, large wildfires can cause long-lasting economic hardship for communities that depend on forest product industries. In addition, they can have far-reaching effects on air quality; wildfire smoke plumes are rich in toxic air pollutants, such as aldehydes, benzo[a]pyrene, carbon monoxide, ketones, nitrous oxides, organic acids and ozone (Chepesiuk, 2001; Scala et al., 2002; Sapkota et al., 2005; Langford et al., 2006). In July 2002, due to unusually large-scale air movements, smoke from large forest fires near James Bay in northern Quebec formed dense haze clouds that drifted without significant dispersion to the East Coast, a distance of over 1,000 kilometres. There and along the way, the smoke adversely affected both outdoor and indoor air quality, and caused short-term but significant health risks for millions of inhabitants of Baltimore and other major cities in the northeastern U.S. (Scala et al., 2002).

Research on the human health impacts of wildfires in the Canadian context is limited, and the results have been mixed. Although the findings of one Canadian study of rural residents in northern Saskatchewan were not conclusive with respect to the relationship between wildfire smoke and hospitalizations (Langford et al., 2006), a more recent study of the health and economic effects of a major wildfire in Chisholm, Alberta, estimated that costs related to the impairment of the health and well-being of the affected population amounted to between $9 and $12 million, second only to the cost of lost timber. The estimate took into account the increased risks of mortality, restricted activity days, lost wages and acute respiratory symptoms due to wildfire smoke (Rittmaster et al., 2006).

3.3.6 Storms and Other Extreme Weather Events

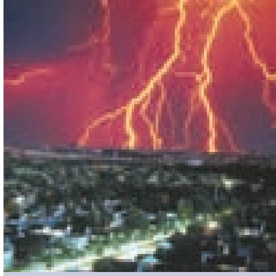
3.3.6.1 Tornadoes

Tornadoes are violent destructive whirlwinds characterized by a funnel-shaped cloud that descends from thunderstorm clouds to the ground. The funnels can vary greatly in size, speed and the amount of damage they can cause. Tornadoes most usually occur in southern Ontario and Quebec, southeastern Manitoba, southern Saskatchewan, and southern and central Alberta.

Barrie, Ontario tornado, May 1985

An exceptionally strong tornado hit Barrie, Ontario, on the afternoon of May 31, 1985, killing 12 people, injuring 281 people, and destroying and damaging many buildings. Those who died had received severe injuries, and almost all died before they reached a hospital. Nearly one half of the serious injuries were to the head and/or neck (49%), and consisted mostly of concussions and brain injuries, with less serious wounds located mostly on legs and arms. Flying objects, including broken glass, caused many of the wounds.

Many of the 605 houses along the tornado path had their roofs or upper floors torn off, windows shattered or brick walls blown apart, while some were lifted off their foundations or destroyed completely. About 200 of these houses were left uninhabitable. In addition, 16 factories were destroyed and 400 people were left at least temporarily unemployed (Etkin et al., 2002).



The Canadian Disaster Database lists 31 disasters caused by tornadoes in Canada from 1912 to 2005 (PSEPC, 2005a). Of these, one occurred in Nova Scotia, seven (22%) in Quebec, 13 (42%) in Ontario, four each (13%) in Saskatchewan and Alberta, and three (10%) in Manitoba. They caused 142 deaths (an average of 4.6 deaths per tornado), injured 1,930 persons (an average of 62 per tornado) and caused the evacuation of nearly 6,500 people. The most destructive tornado in Canada happened on July 31, 1987, in Edmonton, Alberta. It killed 27 people, injured about 600 and led to the evacuation of approximately 1,700 people.

Most tornado occurrences in Canada do not result in injuries and deaths and are therefore not captured in the Canadian Disaster Database. The average number of tornadoes per year is sixteen each in Alberta, Saskatchewan and Ontario; nine in Manitoba; five in Quebec; and one each in Nova Scotia, New Brunswick and Newfoundland and Labrador. The annual number of tornadoes in Canada seems to have increased between 1950 and 2000, from fewer than 10 to about 40, but this could be partly due to an observation bias resulting from population growth, better communications and more intensive news media coverage (Eisen, 2000). If this trend were confirmed, and were to continue along with the growth of communities in southern Canada, the Canadian population would face an increasing risk to its health and well-being from tornadoes.

3.3.6.2 Freezing rain and ice storms

Between the months of December and April from 1900 to 2000, six of seven major ice storms occurred in eastern Canada; the other was in Manitoba (PSEPC, 2005a). Of these events, the 1998 Ice Storm in early January in the northeastern U.S. and eastern Canada caused the greatest damage, and the greatest number of fatalities and injuries. Electrical power failures caused by the collapse of towers and poles, and other damage to transmission lines, affected over 1.6 million Canadians, in many cases for several weeks. An estimated 2.6 million people could not perform their ordinary work at all or could do so only partially, and economic losses amounted to $5.4 billion. Many thousands had to be evacuated to emergency shelters. The 1998 Ice Storm caused 28 deaths in Canada, mostly due to injuries resulting from the indoor use of open flames, barbecues, or propane or kerosene heaters that caused carbon monoxide poisoning or fire; only four people died of hypothermia. This natural catastrophe was exacerbated by the unpreparedness of governments, power transmission agencies, telecommunications enterprises and citizens alike to an event of this magnitude and duration (Lecomte et al., 1998).

3.3.6.3 Thunderstorms and lightning

Thunderstorms are violent winds accompanied by lightning, thunder, and often also by rain or hail, or tornadoes. They most often occur during spring and summer (Environment Canada, 1995). Lightning flashes created by thunderstorms occur mostly in low-lying areas in southern Canada. Since 1998, the Meteorological Service of Canada has operated a lightning detection network. This network has made possible the identification of lightning "hot spots" and has helped to make severe weather alerts and warnings more accurate. It can also be used to determine where lightning strikes might start wildfires. Maps showing lightning activity in Canada, as well as lightning safety information, are available from the Environment Canada Internet site (Environment Canada, 2003b, 2003c, 2007b).

In Canada an average of six to 10 people are killed each year, and another 90 to 160 are injured by lightning (Environment Canada, 2003a; ICLR, 2007). Young, healthy survivors of lightning strikes have been known to suffer from debilitating long-term damage to their nervous systems (Cooper, 1998). However, because there are few studies of medical records documenting lightning-related injuries and deaths, and many of the numbers appear to be based on news reports, it is likely that the number of people hit by lightning in Canada is under-reported. During the past 100 years, the rates of death and injury resulting from lightning strikes have declined considerably, despite a significant increase in population. In part, this may be due to better lightning protection systems for buildings, the concentration of much of the population in cities where building protection has increased in comparison with rural areas, improved individual awareness and protective behaviour, and improved weather forecasting (Aulich et al., 2001).

3.3.6.4 Hurricanes and related storms

Hurricanes (tropical storms or cyclones) consist of very strong winds (with speeds of 120 km/h or more) accompanied by heavy rain and lightning, often initially forming a spiral pattern. They generally originate over the warm waters of the southern Atlantic or in the Caribbean, and move toward Canada along storm tracks that usually pass along the East Coast or through the eastern U.S. They reach Canada at fairly frequent intervals; three to four tropical storms or hurricanes pose a threat to Canada or its territorial waters each year (Environment Canada, 2004a). The frequency of intense hurricanes is likely to increase as a result of climate change (IPCC, 2007d).

In 1985, the Meteorological Service of Canada (Environment Canada) established the Canadian Hurricane Centre (CHC) in Halifax, Nova Scotia. The CHC advises Canadians on the threat of hurricanes and tropical storms so that they can take necessary precautions to protect their health and property.

From 1950 to 1999, Ontario, Quebec, Atlantic Canada and British Columbia experienced 18 disasters related to tropical cyclones (typhoons and hurricanes), resulting in extensive damage and 137 deaths. During the same period, Canada experienced 145 disasters related to other major storms, accounting for 499 deaths. A significant number of these fatalities occurred in weather-related marine accidents such as the wreck of the "Edmund Fitzgerald" on Lake Superior in 1975 (29 deaths) and a 1982 blizzard off the coast of Newfoundland that cost 117 lives when an oil rig and an ocean-going vessel sank (PSEPC, 2005a).

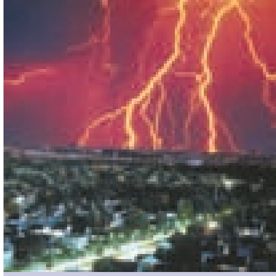
The two tropical storms that probably had the greatest impact on Canada during the last 100 years were Hurricane Hazel, which passed through Ontario and Quebec in August 1954, and Hurricane Juan, which passed through Nova Scotia in late September 2003. Hurricane Hazel alone resulted in 81 deaths and over 7,400 evacuations.

Photo Credits: Peter Young

Damage from Hurricane Juan, 2003

The greatest mortality originates from the secondary disasters that are triggered by hurricanes, such as small tornadoes, flash flooding and storm surges. Historically, in the U.S., nine out of 10 deaths from a hurricane are directly correlated with the preceding storm surge (National Oceanic and Atmospheric Administration (NOAA), 2005). Individuals in the storm path consistently underestimate a hurricane's ability to cause coastal flooding, and many are caught unprepared for the consequences.

Winds are the second deadliest aspect of a hurricane. They are often responsible for property damage, including the collapse of houses and other structures. Crushing injuries caused by the collapse of structures, similar to injuries caused by earthquakes, are common during severe storms especially in areas with substandard construction. Breaking windows and doors, caused by flying objects or wind pressure, are common precursors to major damage to a building, and can cause injuries as well (WHO, 1989).

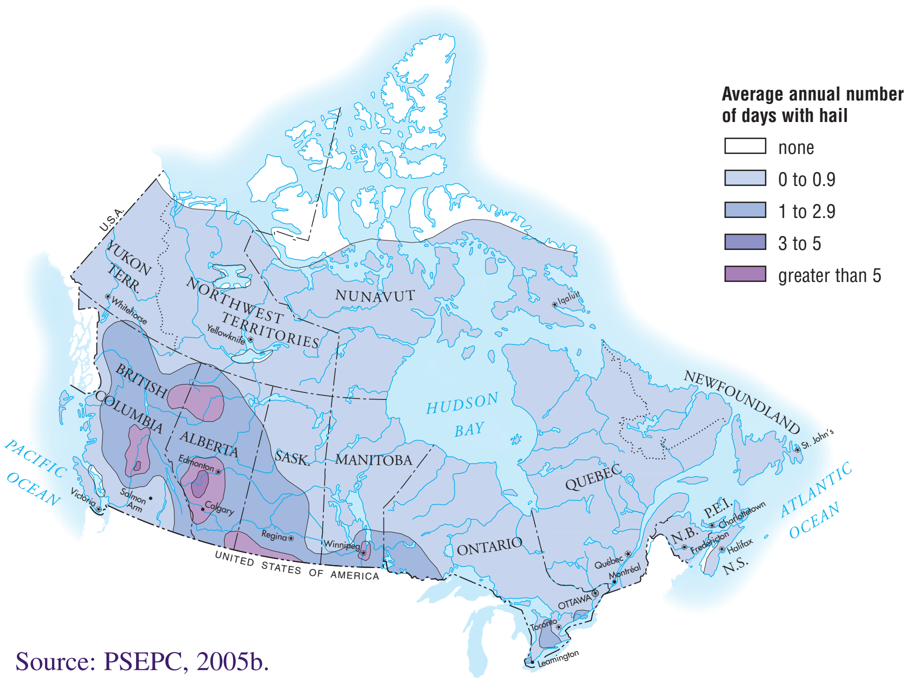


Like other natural disasters, hurricanes typically produce longer-term, yet more intangible, psychosocial impacts. Little research on this subject has been done within the Canadian context. In the aftermath of Hurricane Andrew (1992) in northwestern Bahamas and southern Florida, 30% of respondents in the most affected areas reported experiencing major depression, while a further 20% reported anxiety disorders (David et al., 1996). Parker (1977) and Hutton (2005), in a study of Cyclone Tracy (1974), which destroyed Darwin, Australia, concluded that stress arising from the event could be classified into short-term “mortality stress” (fear of injury or death) and longer-term “relocation stress” related to the loss of possessions, support networks and familiar patterns of interaction. Cyclone Tracy killed 30 and left 100 people hospitalized. One conclusion from the research is that people’s capacity to recover from psychosocial impacts is linked to basic health determinants (Hutton, 2005).

3.3.6.5 Hailstorms

Hail consists of ice pellets that are produced during thunderstorms and are typically larger than 5 mm; on rare occasions pellets may reach the size of an orange or grapefruit. In Canada, major hailstorms tend to occur most frequently in southern and northwestern Alberta, in the southwestern interior of British Columbia, southern Saskatchewan, and less frequently in southern Ontario and Quebec, especially along the St. Lawrence Valley (Figure 3.5).

Figure 3.5 Average frequency of hailstorms in different regions of Canada



Source: PSEPC, 2005b.

Of the 25 hailstorms listed in the Canadian Disaster Database that occurred between 1985 and 1998, 21 (70%) took place in the Prairie provinces. They caused damages of $1.95 billion, mainly through the destruction of agricultural crops and damage to automobiles, buildings and other property. The most frequently and most severely affected city during this timeframe was Calgary, with eight major hailstorms and total damages exceeding $1.4 billion (PSEPC, 2005b). Information on hailstorms in the Canadian Disaster Database (PSEPC, 2005a) attributes seven deaths and no injuries to this hazard since 1900.

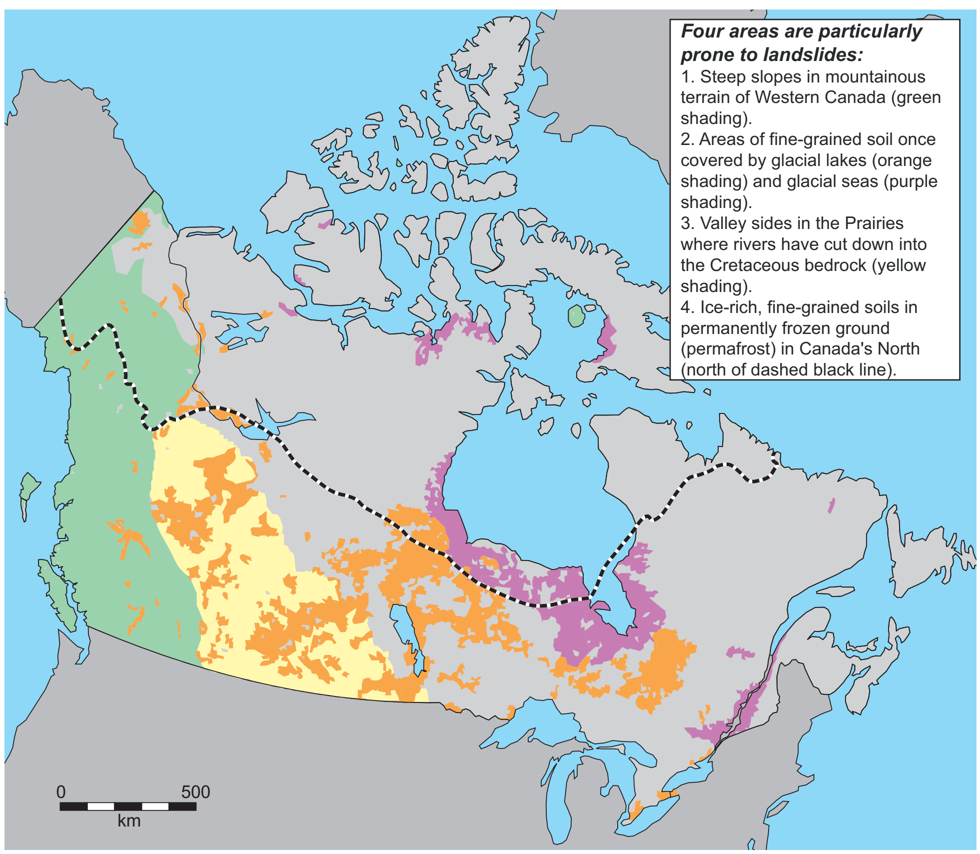
3.3.7 Avalanches, Rock-, Mud- and Landslides, and Debris Flows

A warmer climate increases the rate of evaporation, atmospheric transport, and precipitation as either rain or snow. Mountain regions are subject to heavy rains or snowfalls, and may experience glacier, snowfield or permafrost thaw. Therefore, the risk of avalanche and of excessive runoff that can trigger rock-, mud- and landslides or debris flows is likely to increase in these regions as a result of climate change.

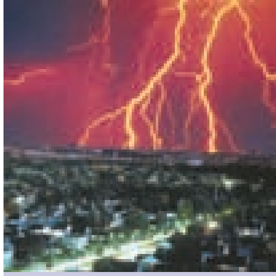
In Canada, mountain regions with steep slopes and heavy precipitation are found in the Rocky Mountains in British Columbia, Alberta and Yukon, as well as in northeastern Quebec and Labrador, and along the Great Lakes-St. Lawrence shorelines and the Atlantic coast (Evans et al., 2002; Atlas of Canada, 2007b). The geographic features of these areas favour increased precipitation, which during winter may result in snowslides (avalanches). In addition, the infiltration of rainwater and meltwater into soils, subsoils and rocks creates unstable layers that are highly susceptible to land-, mud-, rock- and debris slides.

The busy transportation and communications corridors along the river valleys of the Rocky Mountains, which are also lifelines for the communities depending on them, are at high risk of catastrophic avalanches and landslides, rockfalls and mudslides. This risk may be increased by greater precipitation resulting from a warmer climate (Miles & Associates Ltd., 2001; Evans et al., 2002).

Figure 3.6 Regions of Canada with unstable sedimentary rocks or clay deposits that are susceptible to rockfalls, debris flows or landslides



Source: J. Aylsworth, Natural Resources Canada.



In the Peace River lowlands of Alberta, unstable sedimentary Ice Age deposits favour the development of large landslides, which in the past have disrupted highways and partly blocked rivers (Cruden et al., 2000). In southern Saskatchewan, rivers have cut through deep silt and clay deposits that are susceptible to erosion and landslides, and have formed valleys with steep and unstable slopes. The deep gravel, clay, sand and silt sediments of past glaciers and huge lakes, which existed in the Prairie region at the end of the last Ice Age, are susceptible to river erosion and landslides; these threaten parts of Calgary and Saskatoon (NRCan 2005b, 2006b, 2006c). In eastern Canada, the up to 70-metre-thick Leda clay and silt deposits of the former Champlain sea are very susceptible to large-scale slumping and mudflows after heavy precipitation (Hugenholtz and Lacelle, 2004).

Between 1900 and 2005, there were at least 38 major rock-, mud-, debris- or landslides (mostly in British Columbia, but also in Alberta, Quebec and Newfoundland and Labrador) that killed 371 people, injured 56 others and led to the evacuation of more than 2,230 people. Such events have also caused significant economic damage (PSEPC, 2005c; NRCan, 2007). The long-term average occurrence for major rockfalls or landslides in Canada is 1 per 3.7 years. Rockfalls or landslides in western Canada, and landslides of Leda clay in eastern Canada have been the most destructive, and have together caused nearly one-half of the deaths (Evans, 2001). They are of particular concern when they occur along rivers, as this can result in damming or flooding along highways, railways, and power or gas transmission lines, where they can interrupt vital energy supplies and communications, or when they hit human settlements, causing injuries and deaths.

Avalanche at Kangiqsualujjuaq, Ungava Bay

On New Year's Day 1999, an avalanche at Kangiqsualujjuaq, Ungava Bay, an Inuit community in northeastern Quebec, struck a school where the community had gathered for a celebration, as well as six other buildings. The avalanche occurred on a steep slope in an area that frequently experiences heavy snowfalls, killing nine people, five of whom were children under 8 years old, and injuring 25. The avalanche also exposed the 400 to 500 children and adults in the school gymnasium to 100 km/h winds and a temperature of -20°C. Those who were seriously injured had to be transported in the very cold weather and strong winds on snowmobiles and an open flatbed truck on a 300-kilometre road to the nearest community with a hospital. Bad weather prevented medical teams from reaching the site immediately; they reached the community only nine hours after being notified.

3.3.8 Fog, Smog and Mist

Reduced visibility, caused by dense fog along major aerial, marine or terrestrial transportation routes is a common natural hazard in Canada, particularly during the transitional seasons of fall and spring. Low visibility caused by fog, smog or mist was a major contributor to several mass road vehicle collisions and fatalities in the past decade. These weather conditions contributed to three times more fatalities than freezing rain. On average, between 40 and 80 fatal road vehicle collisions occurred annually in Canada between 1988 and 2000 due to fog conditions. However, insufficient driver attention, highway congestion, high speed, increased truck traffic and other factors also typically contribute to accidents of this type (Whiffen et al., 2004).

3.4 EVIDENCE AND IMPLICATIONS OF CLIMATE CHANGE FOR NATURAL HAZARDS IN CANADA

3.4.1 Evidence of Climate Change

Over the past recent decades, numerous national and international efforts have sought to ascertain the causes, progression, and environmental and public health implications of climate change. Among them, the periodic assessment reports of the Intergovernmental Panel on Climate Change are the most comprehensive. Its *Fourth Assessment Report* concluded that warming of the climate system is "unequivocal" and that most of the warming in the last 100 years is very likely due to the observed increase in GHGs, such as carbon dioxide, largely as the result of human activity (IPCC, 2007c). This warming is evident in the increase in global average air and ocean temperatures, sea level rise and the decline in snow and ice cover (IPCC, 2007c). Numerous long-term changes in climate variables have been observed, including changes in precipitation, ocean salinity, wind patterns and aspects of extreme weather, such as droughts, heavy precipitation, heat waves and tropical cyclone intensity (IPCC, 2007c).

These climate variables are important indicators for assessing the risks associated with natural hazards described earlier, such as storms, floods and landslides. By looking at historical records to derive trends, researchers can use sophisticated models to obtain more accurate projections of a future climate. According to the IPCC (2007c), it is "virtually certain" that throughout much of the world there will be further increases in average and extreme temperatures, and that the increase in average temperatures in turn will increase the rate of surface water evaporation and precipitation, thereby increasing episodes of violent weather.

The IPCC provides judgments on the estimates of confidence based on existing scientific literature.[2] Table 3.3 provides information on recent trends and projections for extreme weather events for which there is an observed late 20th-century trend.

Table 3.3 Recent trends and projections for extreme weather events for which there is an observed late 20th-century trend

Phenomenon and direction of trend	Likelihood that trend occurred in late 20th century	Likelihood of future trends based on projections for the 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	Very likely	Virtually certain
Warmer and more frequent hot days and nights over most land areas	Very likely	Virtually certain
Warm spells/heat waves. Frequency increases over most land areas	Likely	Very Likely
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	Likely	Very likely
Areas affected by droughts increases	Likely in many regions since 1970	Likely
Intense tropical cyclone activity increases	Likely in many regions since 1970	Likely
Increased incidence of extreme high sea level (excludes tsunamis)	Likely	Likely

Source: Adapted from IPCC, 2007c.
Climate Change 2007: The Physical Science Basis (Table SPM.2, p.8)

2 Judgments are based on the following scale: virtually certain (>99% chance) that a result is true; very likely (90 to <99% chance); likely (66 to <90% chance); medium likelihood (33 to <66% chance); unlikely (10 to <33% chance); very unlikely (1 to <10% chance); exceptionally unlikely (<1% chance).

3.4.2 Future Climate in Canada and Risks of Natural Hazards

Over the past 50 years, Canada's average temperature has increased 1.2°C. However, this average temperature increase hides important regional variations. The Yukon and the Northwest Territories are experiencing the greatest warming. Across the country, the percentage of precipitation that falls in heavy events is increasing. In Canada, governments at all levels, businesses and the general public have recognized that climate change will increase the risk of certain natural hazards.

Although the work of the IPCC provides projections of trends on a continental scale, its assessment of scientific literature does not constitute forecasts; it cannot predict where and when some of these events will occur or what their intensity will be. It does, however, provide information to identify where action is required to further investigate the risks or introduce measures to protect the health of Canadians.

Regional climate modelling combined with technical aids, such as projections of population changes, information about vulnerability provided by geographic information system tools, and photographic or satellite images and databases, have been used to identify where human populations might be exposed to natural hazards, and specifically those natural hazards that climate change is expected to exacerbate. Such models generally show that in the U.S. and Canada, heat waves and heavy precipitation events are very likely to become more common during this century (Easterling et al., 2000; IPCC, 2007d). In Canada, researchers have access to some regional data from the Canadian Regional Climate Model, Canadian Centre for Climate Modelling and Analysis, Environment Canada. The Ouranos Consortium provides support for the development of this model and has used scenarios based on regional climate models for the analysis of climate change impacts. For example, in recognition of the growing need to plan institutional responses to the effects of climate change, Vescovi et al. (2005) assessed the potential impact of extreme heat on southern Quebec communities. To accomplish this, they integrated climate variables and socio-economic parameters by using a geographic information system tool to create maps that estimate present and future health risks (Vescovi et al., 2005).

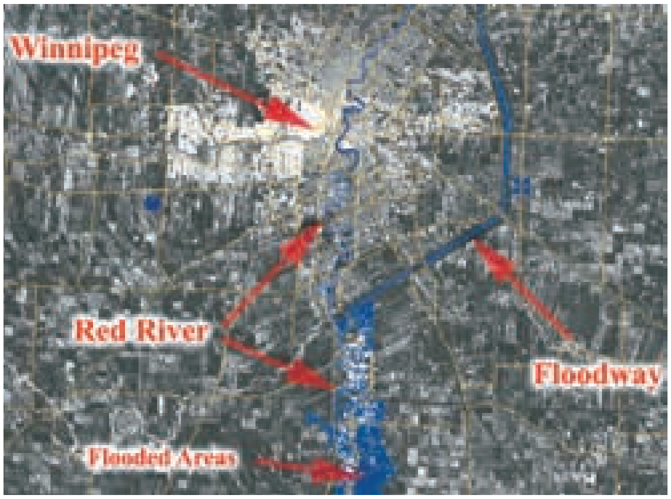
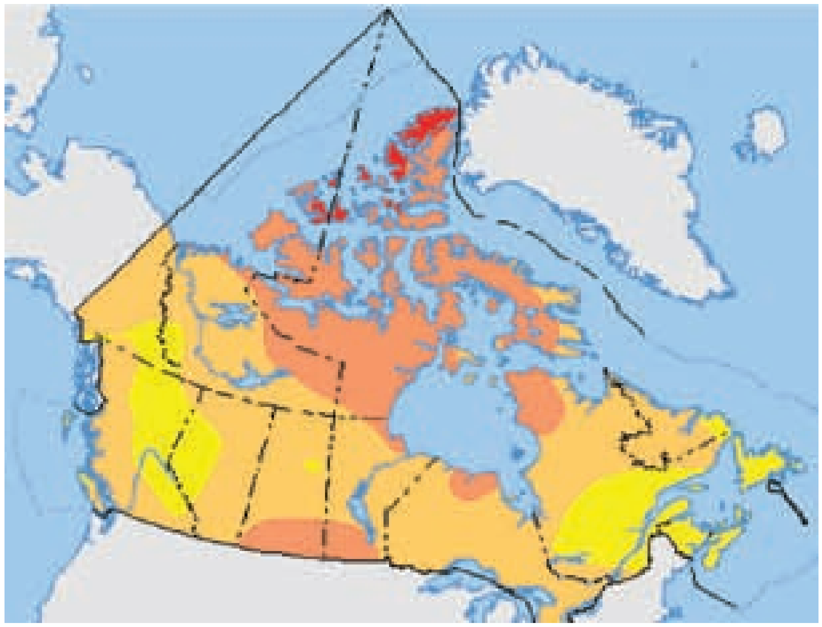


Photo Credits: RADARSAT-1 (c) 2006 Canadian Space Agency, Courtesy NRCan/ESS/CCRS

Figure 3.7 shows a projected scenario of how much the annual mean temperatures might change in different regions of Canada during the years 2040 to 2060. However, there are inherent uncertainties in projections; these increase when calculating what is likely to happen many decades from now compared with what is likely to happen just a few years from now.

Chapter 3

Figure 3.7 Projected increases in annual mean temperatures in different regions of Canada, 2040 to 2060

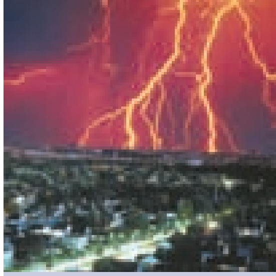


Notes: Projected increases are those compared with annual mean temperatures during 1961 to 1990, based on the Coupled Global Climate Model developed by Environment Canada. Yellow, up to 3°C; light orange, 3–4°C; dark orange, 4–5°C; red, 5–6°C.

Source: Atlas of Canada, 2003.

Climatic changes and weather events that increase slowly over time may also indirectly cause or aggravate natural hazards. For example, they may alter changing structural geologic or geographic components of the landscape (i.e. its geomorphology), or contribute to alterations in biologic components of ecosystems. Such hazards may not become obvious until gradual changes in climate or weather conditions exceed a critical threshold and trigger a disaster in a vulnerable community. For example, a warmer climate in mountain regions can release water from glaciers or thawing permafrost, creating slope instabilities that may result in landslides. In boreal forests in British Columbia, a warmer climate is reducing the winter mortality of bark beetles and leading to beetle population explosions, followed by large-scale forest die-offs and forest fires. Natural Resources Canada has published a series of maps showing regional vulnerabilities of Canadian landscapes and ecosystems to such effects (NRCan, 2000).

The extent to which climate change might cause an increase in weather-related disasters will depend very much on the extent to which communities, governments and individuals recognize hazards and work to mitigate the risk of their occurrence and the potential scope of the effects. A natural hazard triggers a disaster when it interacts with various factors (i.e. physical, social, economic and environmental) that increase the vulnerability of a community to the impacts (F/P/T Network for Emergency Preparedness and Response, 2004). Because natural disasters often occur unexpectedly or with little advance warning, they strain or overwhelm the capacity of affected communities or regions to cope. There is therefore an urgent need to improve capacities to foresee and to cope with climate change and its related natural hazards through greater national and international cooperative efforts.



3.5 INDIVIDUAL AND COMMUNITY VULNERABILITY

3.5.1 Human Health Vulnerabilities to Natural Hazards and Disasters

Risk is the product of the likelihood of an event happening and the vulnerability associated with the population affected (Etkin et al., 2004; F/P/T Network for Emergency Preparedness and Response, 2004; PSEPC, 2007). Consequently, it is important to understand the characteristics of individuals and communities that contribute to their vulnerability to natural hazards, as well as their ability to alleviate and cope with the impacts. This information informs decision making and reduces health risks before, during and after an extreme weather event occurs (PSEPC, 2007). Not all natural hazards lead to disasters. Disasters occur when the demands created by a larger-scale event exceed the community's normal coping resources; this is often called the disaster threshold (F/P/T Network for Emergency Preparedness and Response, 2004).

3.5.2 Vulnerable Individuals

Inherent vulnerabilities are found in populations and communities across Canada. The sections below examine how age, health status, socio-economic conditions and livelihoods affect the ability of people to reduce exposure and protect themselves from natural hazards, as well as cope during an event and recover afterwards.

3.5.2.1 Age

Seniors

The cohort of seniors is rapidly growing in Canada. Between 1981 and 2005, the over-65 segment of society increased by roughly 3% (from 10% to 13%) (Statistics Canada, 2006). This proportion of the population is expected to almost double to 24.5% by 2036. From this date, the seniors population will continue to increase, but at a slower rate, with their population reaching 11.5 million (27.2% of the total population) by 2056 (Turcotte and Schellenberg, 2007). The proportion of the oldest seniors (80 years and over) will also increase sharply; by 2058, about one in every 10 Canadians will be 80 years or older. In 2005, only one in 30 was older than 80 years. Compared with other adult populations, seniors are often more vulnerable because increasing age is highly correlated with increasing illness, disability, medication use and reduced fitness (McMichael, 2003). The specific vulnerabilities of seniors are important to investigate, because they may rely more heavily on the health system to reduce their vulnerabilities (Powell, 2006) and because their proportion within the Canadian population is increasing. It is, however, important to note that age alone cannot be used as the sole predictor of vulnerability; many older people continue to have good health and mobility, and remain socially active into their older years (Powell, 2006).

Nevertheless, aging for most individuals is associated with a decline in general health. Seniors may have limited physical capabilities (Turcotte and Schellenberg, 2007), and their physiological systems are generally less capable of handling stressors, such as extreme heat (McMichael, 2003). Seniors are more likely to have underlying health problems that need regular medical attention, cause limited mobility or impair their ability to care for themselves (Turcotte and Schellenberg, 2007). These vulnerabilities are important because several types of natural hazards (e.g. severe snowstorms, floods) can exacerbate existing conditions causing illness or death (e.g. older men are at increased risk of heart attack while shovelling snow). Furthermore, natural hazards may disrupt the management of existing illnesses or the provision of health services (e.g. unable to attend chemotherapy or dialysis). Seniors are also more likely to be reliant on others to ensure their personal and property safety before, during and after an event (e.g. power outages may leave a

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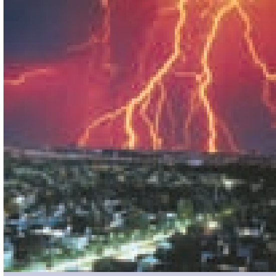
senior without heat). They may also lack the required mobility to move out of harm's way, thus increasing the likelihood of physical stress and harm.

Turcotte and Schellenberg (2007) found that many of the 25 chronic conditions most reported by seniors can influence their vulnerability to natural hazards. These conditions include arthritis, high blood pressure, cataracts, heart disease, diabetes, chronic bronchitis, effects of a stroke, and Alzheimer's or other dementia. It should be noted that stress tends to decline with age, and seniors are less likely to report emotional distress following a disaster (Powell, 2006; Turcotte and Schellenberg, 2007).

Seniors are at particular risk for heat-related illnesses and death because heat tolerance and thermoregulatory capacity decrease with age (Flynn et al., 2005). When a heat wave struck France in August 2003, causing almost 15,000 excess deaths, the observed excess mortality first affected those 75 years of age and over (Vandentorren and Empereur-Bissonnet, 2005). However, excess deaths were also severe for 45- to 75-year-olds (Vandentorren and Empereur-Bissonnet, 2005). In addition, medications commonly used by seniors, such as those used to treat chronic cardiovascular disease, may exacerbate the effects of extreme heat along with the effects of physiological changes associated with aging (Flynn et al., 2005).

Seniors are often on fixed incomes, which can make it more difficult for them to meet additional costs associated with natural hazards. For example, limited income may mean that individuals are unable to purchase adequate insurance coverage or an air conditioner, or to pay to replace property losses. Furthermore, they are less likely to apply for and receive financial aid (Powell, 2006), leaving them overwhelmed and unable to cope or recover from their losses (Shrubsole, 1999; Soskolne et al., 2004). In addition, medical expenses resulting from a natural hazard, such as unexpected prescriptions, ambulance rides or mental health services, can have a significant economic impact on low-income seniors who are without insurance.

Because networks of family and friends tend to decrease in size as people age, social isolation and loneliness tend to increase (Hall and Havens, 2002). Although only 2% of Canadian seniors reported that they had no close friend or relatives to talk to (Turcotte and Schellenberg, 2007), during a disaster or natural hazard severe disruption in existing networks can occur, and individuals may be hidden from social service providers and left alone to cope with the emergency (Powell, 2006). These contacts and networks are often key to maintaining good health or managing an illness for seniors. For example, a close friend or relative living in another community may not be able to provide timely assistance. Seniors are also more likely to be fearful during an event. During the Chicago heat wave, fearing for their safety, seniors were more likely to keep their windows and doors closed, which increased their risk of heat-related illnesses and death (Klinenberg, 2002).



Children

Statistics Canada (2006) estimates that approximately 24% of Canada's population are children (aged 0–19 years). Young children are especially vulnerable to natural hazards because their perception of danger is not fully developed, and they require more assistance to move out of harm's way and to adopt protective behaviours. After a natural hazard event, they are particularly at risk from subsequent hazards such as water, soil and air contamination. This is because their physiology, metabolism, and behaviours increase the risk of disease or illnesses. Furthermore, disruption of their growth and development at critical times may cause irreversible damage, and their exposures to contaminants per unit of body mass are higher via water and air than an adult (Tamburlini, 2002; Health Canada, 2005b).

Young children and infants are much more vulnerable to water- and food-borne illnesses than adults because they have immature immune systems and are unable to avoid risks alone (e.g. follow boil water advisories) (Jermini, 2002; Pond, 2002). Children also tend to take in more water and food per unit body mass than adults, which increases their exposure to water- and food-borne pathogens (Health Canada, 2005b). For example, after a flood a child is more likely to ingest or be exposed to contaminated water than an adult because of their inability to understand the health hazards associated with floodwater contamination, as well as their hand-to-mouth behaviour.

Thermoregulatory capacity in children is underdeveloped until 1 year of age, and their higher ratio of surface area to body mass (up to age 5) makes them more vulnerable to heat stress (Longstreth, 1999; Mathieu-Nolf, 2002; Health Canada, 2005b). As a result, infants are particularly at risk during heat waves. However, their greatest vulnerability to extreme heat may be that they are reliant on caregivers to be diligent by requiring them to drink fluids and retreat to cooler environments (Health Canada, 2005b).

As young children are dependent on others for their health and well-being and safety, they also carry the vulnerability of their caregivers. Compounding this situation is the fact that they have little or no means with which to change their situation. For example, children from low-income families are more vulnerable to heat waves if they reside in substandard housing without access to air conditioning. Children rarely have the capacity or resources to reduce their own exposure or vulnerability; they do not go to cooling centres on their own, may not understand how to relieve the stresses from heat (e.g. more fluid intake), or adopt other protective measures.

Natural hazards can also contribute to psychological trauma during and after the event (Heinz Center, 2002; Shea, 2003; McDermott et al., 2005). In his review of hazard literature, Shrubsole (1999) found that children's reactions to a natural hazard depended, in part, on the ability of their parents to deal with it; if the parents handled the disaster period adversely, so did the child. It was also found that children are more at risk from the psychological trauma of natural hazards because they have lower coping capabilities, and perceive the world according to their level of cognitive and emotional development Shrubsole, 1999; Hutton, 2005). Children can experience any number of psychological illnesses as a result of the trauma inflicted by a disaster. The effects can be as severe as losing recently developed skills, eating and sleeping disorders, as well as behavioural issues (Heinz Center, 2002; Hutton, 2005).

3.5.2.2 Underlying health problems

Chronic health conditions, acute illnesses, neurological disorders, mental illnesses (including addictions) and limited mobility increase the vulnerability of individuals to natural hazards. Chronic and acute illnesses are exacerbated by subsequent degraded environmental conditions and contamination, resulting in a lack of safe food and clean drinking water, and exposure to disease-causing pathogens and poor air quality (Mokdad et al., 2005). Illnesses that require regular medical attention can be worsened by the stress of a disaster, and can lead to death. Problems arise when people are not able to access required medications or life-sustaining treatments. Natural hazards may damage health equipment that is required to sustain life, such as ventilators or oxygen generators (Powell, 2006).

Access to medical services during an event or disaster is essential for individuals with a compromised health status. High demand for needed medical services, as well as availability of medication and equipment, can become life-determining factors. Health centres can be overwhelmed with ill or injured people during an event or disaster, placing chronically ill patients at further risk. In addition, emergency shelters may not have the equipment to deal with their special needs (Powell, 2006). Those with limited mobility will likely require aid from others to evacuate or reach a safer location. For example, individuals who are bedridden in nursing or extended-care facilities, who have spinal cord injuries or who have acute arthritis which restricts movement will require the assistance of others.

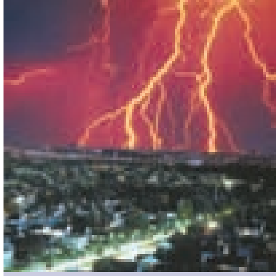
Neurological and mental illnesses can have a serious impact on a person's ability to function effectively in the face of a natural hazard event or during a disaster. Mental illness can take various forms, such as mood disorders, schizophrenia, anxiety disorders, personality disorders and eating disorders (Health Canada, 2006c). Neurological illnesses include brain diseases that impair cognitive functions, such as Alzheimer's and dementia (National Advisory Council on Aging (NACA), 2004). Depending on the illness, a hazardous event may cause serious disturbances in thinking, behaviour or mood. As a result, mental illness can affect one's ability to make the right decisions regarding health and safety before, during and after a natural hazard event or disaster. It should be noted that McMurray and Steiner (2000) concluded that patients with severe mental illness who had access to psychiatric services during the 1998 Ice Storm in Quebec coped well with the disaster.

Drug or alcohol dependency also increase vulnerability to natural hazards. Long-term consequences of substance abuse include impairment of judgment, interference with learning and retention of new material, and loss of self-control (Health Canada, 2007a). In addition, individuals on specific medications or those addicted to drugs are less capable of thermoregulation during heat waves (McGeehin and Mirabelli, 2001). Individuals who are impaired, or preoccupied with obtaining a substance, are less likely to make appropriate decisions about their health and safety, before, during or after a natural hazard event or a disaster.

3.5.2.3 Socio-economic conditions

Two key determinants of health are socio-economic status and education. Those with higher socio-economic status and education tend to have better overall health (Public Health Agency of Canada (PHAC), 2004). Income and education allow for greater control over one's circumstances, especially during stressful situations. Those with higher income and education usually have more coping options available to them before, during or after a disaster (PHAC, 2004). Education equips people with skills and knowledge to access the information and resources to better their outcomes.

Canadians with low literacy levels are more likely to have low income or be unemployed (PHAC, 2004). Lower income often creates conditions that limit the ability of individuals and families to reduce their risk to natural hazards by, for example, choosing where one lives (e.g. avoiding floodplains, avalanche chutes), adopting protective behaviours and adaptations



(e.g. air conditioners), and accessing measures that facilitate recovery (e.g. insurance, financial resources). Although it is possible to protect one's self and limit exposure to some hazards, it is not possible to avoid all exposures. If low-income individuals have a harder time staying healthy under "normal" conditions, when a natural hazard occurs they are especially vulnerable and their ability to recover may be limited.

Homelessness is often associated with drug and alcohol addiction, and mental illness (Fisher and Breakey, 1991; Hwang, 2001). People without permanent shelter are more vulnerable to extremes in temperature because they are more exposed (Hwang, 2001), and they are also less able to physiologically adapt to extreme heat (Koppe et al., 2004). Furthermore, they may not have the means to protect themselves from the effects of extreme cold, such as hypothermia and frostbite. A study in Montreal showed that homelessness, along with alcoholism, mental illness and advanced age increased the risk of cold injuries (Koutsavlis and Kosatsky, 2003). Other groups at risk of cold weather-related injuries or death are people in frail health and outdoor workers.

3.5.2.4 Aboriginal peoples: First Nations, Inuit and Métis

The Aboriginal population of Canada comprises First Nations, Inuit and Métis peoples. In 2001, 3.4% of Canadians identified themselves as Aboriginal (Statistics Canada, 2003). More specifically, 2.1% identified themselves as First Nations, 1% Metis and 0.1% as Inuit. Children under 14 years of age represent 33% of the Aboriginal population, compared with 19% in the non-Aboriginal population (Statistics Canada, 2003). Thus, many Aboriginal communities have a high proportion of children; as discussed earlier, children have particular sensitivities, including the fact that they are dependent on adults to protect them from hazards.

Many factors come together to create unique vulnerabilities for Aboriginal people and communities, such as poor health status and socio-economic conditions and inadequate infrastructure. Compared with the general population, there is a higher incidence of some chronic diseases among First Nations and Inuit people. For example, the prevalence of heart disease and diabetes are 1.5 and 3-5 times higher among Aboriginals, respectively, and 15% of new HIV infections occur in Aboriginal people (Health Canada, 2000; Health Canada, 2006b). Alcohol consumption has been identified as a problem in some Aboriginal communities, as is the increasing use of prescription or illicit drugs (Health Canada, 2006d). Poor health status renders individuals more vulnerable and less resilient to natural hazard events.

Vulnerability among Aboriginal people is compounded by existing infrastructural deficits (e.g. roads, housing, water and wastewater infrastructure). In 2000–2001, only 55.8% of homes on First Nations reserves were deemed adequate (Health Canada, 2007b). The isolation of many First Nations and Inuit communities makes evacuation and access to emergency and health services difficult, traumatic and costly during disasters. Further information on the vulnerabilities of Aboriginal people and communities is provided in Chapter 7, Health Impacts of Climate Change in Canada's North.

A warmer climate causes new natural hazards for Inuit

Aboriginal people who live off the land, especially Inuit, are vulnerable to climate change because their environment is changing rapidly and becoming more dangerous. A warmer climate is compromising the health and safety of Inuit people; melting sea ice and permafrost are causing damage to infrastructure, such as houses and health centres, and decreasing the availability of some traditional wildlife for food. Deviations from a traditional diet have been linked to a decrease in nutritional status. More unpredictable weather also makes travel dangerous (Health Canada, 2005b). Although a warmer climate may be outside the definition of a natural hazard in terms of an extreme event, it is considered a natural hazard for the Inuit people—it is a threat that increases the risk of adverse health outcomes, such as poor nutrition, injury and death (Arctic Climate Impact Assessment (ACIA), 2004).

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3.5.2.5 People relying on natural resources

Individuals whose livelihoods depend on natural resources as a source of employment or as a direct source of food for themselves and their family can be particularly vulnerable to the impacts of natural hazards. Financial concern is one of the most important aspects of farming that tends to increase personal stress and distress levels (Deary et al., 1997; Simkin et al., 1998; Soskolne et al., 2004). Stress in farmers, which is related to financial pressures, has the potential to lead to many negative health outcomes such as depression or suicide (Malmberg, et al., 1997). Stress in agricultural occupations also negatively impacts family life (Plunkett et al., 1999).

Industries that rely on natural resources cannot completely protect their assets from natural hazards and changes in climatic conditions. Droughts can cause substantial decreases in crop yields and large export losses of agricultural products unless farms are equipped with reliable irrigation. This can lead to an increased reliance on financial assistance and crop insurance payouts. When climate-related stressors affect natural resources, they can affect an individual's employment, regardless of whether the employer is small, privately owned, or a large industry. Infrastructure may be affected as well. Increased storm activity, including storm surges and high winds, can cause costly damage to infrastructure that underpins business operations. This was the case in Atlantic Canada in January 2000 when a storm surge drove blocks of ice through coastal buildings and damaged fishing equipment (Canadian Institute for Climate Studies (CICS), 2000). For freshwater fisheries, drought will likely have the largest impact by decreasing water levels; this would increase salinity, and could degrade shoreline wetlands and facilitate the invasion of exotic or aggressive aquatic plant species (NRCan, 2004a). Loss of employment within a predominant sector of a small community can also have a domino effect on the provision of many services within that community and on the employment of individuals in other sectors (Heinz Centre, 2002).

3.5.3 Vulnerable Communities

When individuals in a community are vulnerable, the vitality of that community is often affected. Likewise, when the characteristics of a community make it more vulnerable to a natural hazard, individuals are at greater risk. Lessening community vulnerability will ultimately reduce individual vulnerability and minimize negative health outcomes. Communities become more vulnerable because of increased population and property density, human habitation in high-risk areas, aging infrastructure, poor urban planning, and inadequate municipal capacity and resources, and emergency planning (McBean and Henstra, 2003; Etkin et al., 2004).

3.5.3.1 Infrastructure

Infrastructure refers to facilities with permanent foundations that are the essential elements of a community, and support human activity and improve the quality of life within the community. It includes various types of buildings and structures, such as hospitals and schools, as well as facilities like roads, railways, harbours, power stations, and water and sewage lines. Infrastructure is usually designed for a specific climate.

Questions arise as to whether Canada's current infrastructure will meet the challenges posed by climate change and the projected increase in natural hazards. It is well documented that impacts from a natural disaster can be exacerbated by weaknesses in infrastructure (Henstra et al., 2004). Damaged or destroyed infrastructure has the potential to affect health and well-being. Soskolne et al. (2004) found, in their study of newspaper reporting on disasters in Alberta, that service interruption was one of the most commonly reported outcomes associated with extreme weather, including washed-out roads, disruption of power, telephone and water services, closure of medical facilities (e.g. hospitals) and water contamination. Palecki et al. (2001) reported similar impacts from the July 1999 heat wave in the midwestern U.S., including a record-setting usage of electric power, a burned-out transformer causing 72,000 residents to lose power at the peak of the heat wave, buckling highways leading to road closures, and small communities with well-water systems facing problems in meeting water demand. The 1998 Ice Storm in eastern Canada caused the collapse of thousands of hydro towers, resulting in massive power outages. Many people were without power for weeks during the coldest time of the year.

While all urban infrastructure is important, special attention needs to be paid to a community's critical infrastructure. Critical infrastructures are the "physical resources, services and information technology facilities, networks and assets which, if disrupted or destroyed, would have serious impacts on the health, safety, security or economic well-being of Canadians" (PSEPC, 2005a). They include infrastructure related to energy and utilities, communications and information technology, finance, health care, food, water, transportation, safety, government and manufacturing. Community vulnerability often depends on where critical infrastructure is located, and its physical capability to withstand the assault of a natural hazard event. Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada, examines concerns regarding the state of critical infrastructure in Canada and its implications for vulnerability to the health impacts of climate change.

Photo Credits: Peter Young

Damage from Hurricane Juan, 2003

Infrastructure can also exacerbate the effects of a natural hazard event. For example, materials used in buildings and infrastructures are directly related to the urban heat island effect. This effect is primarily due to an absence of vegetation and the thermal properties of dark surfaces, such as paved roads and tarred rooftops (Frumkin, 2002). Some simple changes in building design and infrastructure, such as living or green roofs and reflective light-coloured surfaces, can mitigate this effect. As well, cities with a high density of impervious surfaces severely limit the potential for the infiltration of water, causing increased surface runoff. This runoff has the potential to overwhelm storm-sewer systems during intense precipitation events, possibly increasing the vulnerability of the population to environmental and public health impacts.

Many cities across Canada face significant pressures from aging infrastructure and the needs of growing populations. The level of deterioration and the age of current infrastructure may render it vulnerable in today's climate (Henstra et al., 2004), let alone for future climate for which extreme weather events are projected to increase. The capacity required to upgrade infrastructures, or to make significant new capital investments, often exceeds the capacity of one level of government (Federation of Canadian Municipalities, 2003). Smaller and rural communities face particular pressures when it comes to investing in infrastructure to protect their populations. In rare cases, protection from and/or mitigation of natural hazards is not possible; relocation of the community is the only option. In many northern communities, infrastructure such as roads and buildings is in danger because of shorter winters, a longer thaw season and melting permafrost (ACIA, 2004).

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3.5.3.2 Public health and emergency response services

A successful emergency management program aims to provide communities and individuals with appropriate health care and emergency social services in times of disaster (F/P/T Network for Emergency Preparedness and Response, 2004). Primary health care services are the first point of contact with the health care system and include basic emergency services. Secondary services, such as hospitals and long-term care institutions, provide more specialized care (Health Canada, 2006a). Both primary and secondary services are affected to various degrees during natural hazard events or disasters. Hospitals and emergency centres not only have to cope with people who have acute injuries and illness as a consequence of the event, but also those who can no longer manage their pre-existing health conditions (e.g. diabetes), and those with health conditions that may be exacerbated by the event (e.g. HIV/AIDS) (Powell, 2006).

A natural hazard can quickly become a disaster if the health service infrastructure is not prepared or cannot respond. This may require relocating or retrofitting health infrastructure, such as hospitals, clinics and nursing homes that could be severely damaged by disasters; ensuring continuity of services for current or emergent individuals during times of internal system disruptions and external community impacts; and providing an alternate system of communication (F/P/T Network for Emergency Preparedness and Response, 2004).

Case study: Lessons from the tornado at Pine Lake, Alberta, 2000

In July 2000, a tornado, with winds of up to 300 kilometres per hour, struck a campground and trailer park at Pine Lake, Alberta, killing 12 people and injuring more than 140. Close to 1,000 people were displaced from the site as their recreational vehicles were damaged (PSEPC, 2005a). The experience at Pine Lake demonstrates the importance of disaster planning, the critical role of communications systems and the response of paramedics and other emergency personnel. Sookram et al. (2000) noted areas requiring improvement for future disaster responses, in particular ensuring that the response is proportionate to the disaster and strengthening communication systems (primary and alternate).

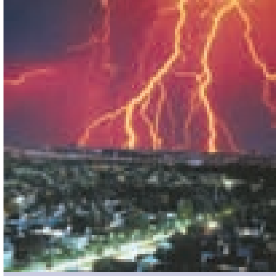
More ambulances than required were dispatched to the disaster site; this resulted in no ambulance coverage for emergencies in other communities. An organized dispatch system coordinating the various emergency medical services should balance the needs of the disaster scene with the needs of the surrounding communities. In addition, the cellular communications system failed, and reliable information could not be passed from the disaster site to the receiving hospitals. A potential solution identified for future disasters was a mobile communications trailer to be used as an on-site command and control post.

Photo Credits: Dan Kulak

Tornado damage at Pine Lake, Alberta, 2000

In the absence of reliable casualty estimates, Calgary and Edmonton hospitals fully activated their disaster plans; hospital beds were vacated, city ambulances were diverted, and physicians and nursing staff were called in. But the number of casualties did not require this level of response. For a disaster of this size, a staged response would have been more appropriate (e.g. call in some extra staff and have others on stand-by) (Sookram et al., 2000). A staged response permits staff rotation and prevents staff fatigue if the disaster proves more serious or prolonged.

Sookram et al. (2000) also reported that this disaster demonstrated that well trained emergency physicians can contribute to on-scene patient care, although to be most effective, physicians should have experience and be familiar with the protocols, equipment and problems associated with field medicine.



Emergency physicians need to be familiar with their hospital's disaster plan, and be prepared to lead or participate in the disaster response. Support services and staff with appropriate training must also be available. Other ways health care institutions and personnel may be vulnerable during an emergency include:

- hospitals that contract out certain essential services (e.g. laundry and food) may have them interrupted during an emergency;
- overcrowding in emergency shelters during a disaster may increase exposure to infectious diseases (e.g. influenza) of health care workers and as a result make them unavailable to support emergency responses (ICLR, 2003)—mass vaccinations could be required; and
- electronic medical records could face access delays of up to days or weeks in the event of a power outage during a disaster, with a consequent delay in care.

3.5.3.3 Urban planning

Urbanization has increased by 66% over the last 50 years in Canada. Approximately 80% of Canadians now live in cities, with 60% living in urban areas with more than 500,000 people (ICLR, 2003). The occurrence of natural hazards in urban areas with large concentrations of people increases the likelihood of disasters. With increased urbanization and population pressures, people are moving into more marginal land, such as coastlines, floodplains, unstable slopes and wildland-urban interfaces (Robert et al., 2003; Roy et al., 2003). For example, there has been a surge in the population of the Lower Mainland region of British Columbia despite the high risk of earthquakes and floods in the area (McBean and Henstra, 2003).

New construction and urban plans and design rarely incorporate adequate resistance to natural hazards, such as tornadoes or flooding. Inappropriate land-use planning puts people in harm's way. The lack of protection or mitigation measures leaves the inhabitants of vulnerable communities to bear the full cost of disaster losses (McBean and Henstra, 2003). This settlement pattern increases the likelihood that the number of people affected by natural hazards will continue to grow. Key to resolving this issue is, among other practices, strategic and smart land-use planning.

3.5.3.4 Community structure and characteristics

Urban communities are highly vulnerable because of greater population densities, placing more people and property at risk (McBean and Henstra, 2003). However, community structure also plays a role in the capacity of communities to adapt to natural hazards. Communities with more "high-risk" inhabitants will require more resources to effectively manage health emergencies. For example, a retirement community has more people with special health needs. In addition, communities with a greater proportion of lower-income families that may have special needs during an emergency will have a lower tax base for resources to implement emergency programs.

Communities can face very different challenges. For example, First Nation communities are often more isolated, making evacuation plans more difficult and emergency medical response times greater. Economic engines of a community, such as agriculture or fisheries industries, may increase a community's vulnerability to natural hazards and disasters. Destruction of infrastructure is likely to have impacts beyond the cost of repairing damage; not only are the services and products lost because of the disaster, but jobs and the community tax base are also reduced. This can have lasting effects on the entire community (Heinz Center, 2002). It is important that communities identify their socio-demographic characteristics and the inherent vulnerabilities to hazards that may exist within or around their boundaries. This knowledge assists decision makers in the design and implementation of programs to improve preparedness and the ability of vulnerable populations to cope. This process is necessary to improve the resilience of the community to the impacts of natural hazards.

3.6 MANAGING RISKS FROM NATURAL HAZARDS AND REDUCING VULNERABILITY THROUGH ADAPTATION

3.6.1 Emergency Management Approach

The field of emergency management is structured around well-defined concepts, approaches and frameworks that should guide the process of adaptation to climate change. However, terminology used in this field and in the field of climate change can lead to confusion because different terms are sometimes used to express similar concepts, while occasionally the same terms mean different things. For example, disaster mitigation and climate change adaptation refer to similar sets of activities—those aimed at reducing risks from hazards. However, in the climate change field mitigation refers to actions taken to reduce the emission of GHGs. In the following sections, the terms disaster mitigation and mitigation are used interchangeably.

Mitigation: The prevention of natural hazards from becoming natural disasters. It includes policies and actions taken before or after a disaster to reduce the impacts on people and property, such as building public awareness and support, developing local and regional plans for land use to prevent inappropriate development in hazardous areas, and changing building codes and standards to protect people, property and infrastructure.

Preparedness: The activities and measures taken in advance to ensure effective response to the impact of hazards, such as the issuance of effective early warnings and the temporary evacuation of people and property from threatened locations.

Response: Actions taken immediately before, during and after a disaster to protect people and property and to enhance recovery, such as emergency public communication, search and rescue, and medical assistance to those in need.

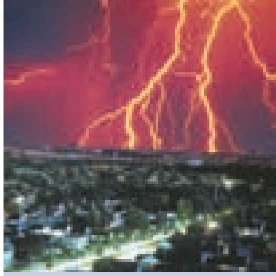
Recovery: Actions taken after a disaster to restore critical systems and return a community to pre-disaster conditions.

Hazard or disaster risk management is defined by the International Strategy for Disaster Reduction as the "systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters" (UN/ISDR, 2004). Emergency management[3] uses a risk-based approach to hazards—that is, a systematic assessment of hazards, threats, risks and vulnerabilities relating to people in a geographic area, or an organization, to develop an effective emergency management plan (PSEPC, 2007). Effective emergency management incorporates overlapping, complementary components: mitigation (prevention), preparedness, response and recovery.

In the international community, there is a growing consensus that emergency management policies must incorporate a greater emphasis on mitigation. The Hyogo Declaration of the 2005 United Nations World Conference on Disaster Reduction stated:

> "We, delegates to the World Conference on Disaster Reduction...are deeply concerned that communities continue to experience excessive losses of precious human lives and valuable property as well as serious injuries and major displacements due to various disasters worldwide... We recognize as well that a culture of disaster prevention and resilience, and associated pre-disaster strategies, which are sound investments, must be fostered at all levels, ranging from the individual to the international levels... We affirm that States have the primary responsibility to protect the people and property on their territory from hazards, and thus, it is vital to give high priority to disaster risk reduction in national policy, consistent with their capacities and the resources available to them." (UN/ISDR, 2005c, p. 1)

3 In the literature emergency management and disaster management are often used interchangeably. For the purposes of this Chapter, the term emergency management will be used.



In addition, based on global consultations held in 2006 which brought together experts in emergency management from around the world, the WHO released *Risk Reduction and Emergency Preparedness: Six-Year Strategy for the Health Sector and Community Capacity Development.* The strategy, which is to inform both developed and developing countries, has the following priorities (WHO, 2007):

- assessing and monitoring baseline information on the status of risk reduction and emergency preparedness in the health sector at regional and country levels;
- institutionalizing risk reduction and emergency preparedness programmes in ministries of health and establishing an effective all-hazard whole-health programme for this purpose;
- encouraging and supporting community-based risk reduction and emergency preparedness programmes; and
- improving knowledge and skills in risk reduction and emergency preparedness and response in the health sector.

Many governments around the world have changed, or are in the process of changing, their disaster management policies to incorporate a greater emphasis on mitigation. Although Canada endorsed the Hyogo Declaration, Canadian emergency management policies do not yet incorporate significant mitigation activities. However, in January, 2008 the federal government released Canada's National Disaster Mitigation Strategy which incorporates disaster mitigation into Canada's evolving emergency management framework. The Strategy sets out a common vision for disaster mitigation activities in Canada through enhanced leadership and coordination, education and outreach activities, scientific research and increased federal, provincial and territorial mitigation investments (PSC, 2008).

Another important element in the development of mitigation policies is federal Bill C-12, the *Emergency Management Act,* which received Royal Assent in June, 2007. It provides for enhanced emergency management activities in Canada by granting the federal Minister of Public Safety the responsibility for exercising leadership relating to emergency management in Canada. To this end the Minister coordinates emergency management activities among government institutions and in cooperation with the provinces. The Act assigns responsibilities for all aspects of emergency management including mitigation, preparedness, response, and recovery to protect Canadians from disasters. Requirements for prevention and mitigation activities in the new Act provide an important opportunity to make progress on adaptation efforts aimed at reducing risks to health from climate-related natural hazards in Canada by adopting a more balanced and comprehensive approach to emergency management.

Canada still faces a number of challenges in implementing a national disaster mitigation strategy (McBean and Henstra, 2003). As a federal state, Canada relies on intergovernmental collaboration for the development and implementation of policies on disaster mitigation. A strong federal desire to move forward with and sustain an initiative may not be sufficient to support the implementation of programs and policies across Canada. There is also uncertainty regarding current risks from natural hazards and existing vulnerabilities, which makes it difficult to identify areas where policies should be targeted to be most effective. More information is needed through community-level assessments and research to develop appropriate responses or mitigation measures to protect health.

As well, because disasters occur infrequently, interest in disaster mitigation can be sporadic and short-lived, and citizens generally perceive a low probability of loss from such events. As a result, officials are not inclined to make adequate investments in mitigation. The post-disaster opportunity and policy window for improving mitigation measures is usually overtaken by the primary goal of returning the community to "normal" as quickly as possible.

Chapter 3

3.6.2 Emergency Management in Canada: Current Capacity and Initiatives

3.6.2.1 Overall capacity and advances in preparedness

Photo Credits: Canadian Red Cross

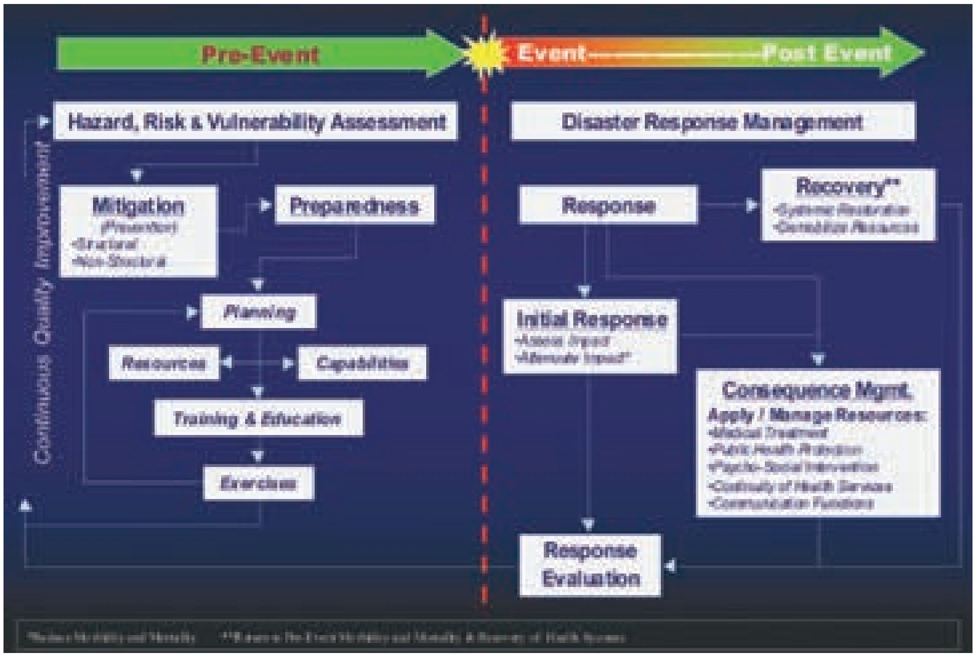
In Canada, all levels of government and a wide range of sectors have important and generally well defined roles in managing risks to health from natural hazards and disasters. Inter-governmental collaboration between federal and provincial authorities is essential for the development and implementation of emergency management policies. Municipal governments play a key role in Canada in reducing risks to health from climate change through their activities related to police, fire and ambulance services, utilities, local public health and social services, and community emergency preparedness and planning. Most emergencies in Canada are local in nature and are managed by municipalities or at the provincial or territorial level (PSEPC, 2005a). Non-governmental organizations (e.g. Canadian Red Cross, Salvation Army), the business community (e.g. insurance companies) and individual Canadians also play key roles in reducing risks from natural hazards.

Concern about existing vulnerability to the impacts of natural hazards on the health of Canadians and their communities has resulted in recent efforts to better prepare for disasters and appropriately manage existing risks. The actions taken by the Government of Quebec to revise and extend public safety legislation to improve the emergency preparedness of local and regional municipalities in response to the Saguenay flood and other events (Beauchemin, 2002) is one example. In Ontario, the new *Emergency Management and Civil Protection Act* stipulates that all communities and the provincial government must establish an emergency management program based on hazards and risks that the people of Ontario may face (Government of Ontario, 2006). The Act provides the emergency powers necessary for the provincial government to react quickly to an emergency (e.g. evacuations, closing private and public places to limit access, disposing of environmental or animal waste) (Government of Ontario, 2006). In recent years, considerable progress has also been achieved within the health sector to develop a more integrated and robust emergency management capacity (Health Canada, 2005b). A number of the actions that have been taken to increase the ability of communities and governments to manage health risks associated with extreme weather events and natural hazards are presented in Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada.

3.6.2.2 Health emergency management

The health sector plays a key role in efforts aimed at protecting Canadians from extreme weather events and natural hazards which can turn into disasters. Health emergency management plans and activities set up processes to guide and prepare the health and social services sectors at all levels of government, or within institutions, for a range of public health emergencies. The National Framework for Health Emergency Management in Canada highlights the key stages and requirements of health emergency management for decision makers (Figure 3.8).

Figure 3.8 National Framework for Health Emergency Management



Source: F/P/T Network for Emergency Preparedness and Response, 2004.

Health emergency management activities are aimed at reducing vulnerabilities, at the individual and community levels, to the risks associated with extreme weather events and natural hazards. The Framework provides information and an organizational structure for Canada's health and emergency social services sectors to properly mitigate hazards, prepare for emergencies, respond quickly and help communities recover (F/P/T Network for Emergency Preparedness and Response, 2004). The Framework is pan-Canadian and trans-jurisdictional in scope in order to ensure that the information is useful to community-based programs, companies in the private sector, local jurisdictions (municipalities, provinces, territories) and federal departments.

Under the Framework, four facets of the health and social services sector are emphasized: physical health (individual perspective), public health (population perspective), emergency social services (societal perspective), and maintenance of activities (organizational perspective). Each facet is examined in every phase of emergency management (i.e. mitigation, preparedness, response, recovery) with a view to minimizing the health impacts associated with natural hazards (F/P/T Network for Emergency Preparedness and Response, 2004). Work continues on the development and implementation of Canada's National Health Emergency System, based on the principles and guidelines set out in the National Framework for Health Emergency Management. Key activities include (Expert Group on Emergency Preparedness and Response, n.d.):

- National Health Incident Management System, which is intended to facilitate a coordinated response capacity across the F/P/T health system during health emergencies or crises;
- Memorandum of Understanding on Mutual Aid, which provides a mechanism for F/P/T governments to provide and to receive assistance from one another during a public health emergency in an efficient and timely manner;
- Pandemic Preparedness Health Operations Coordination Working Group to enhance operational capacity and consistency across all jurisdictions on pandemic issues; and
- National Surge Capacity Strategy to facilitate a timely and efficient response to the increased health demands placed on health care systems across all jurisdictions during emergencies.

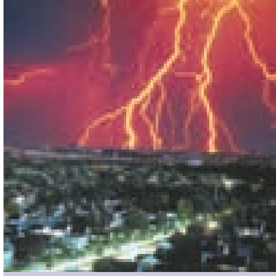
3.6.2.3 Identifying hazards and issuing warnings

The identification and analysis of hazards at the local level is the cornerstone of emergency management and is necessary for the establishment of community response plans. In a survey of eight cities across Canada conducted in 2005 for this Assessment, it was found that all municipalities had identified and analyzed the hazards that were prevalent in their geographic regions (Health Canada, 2005c). Natural hazards, particularly extreme weather events and situations involving hazardous materials, were generally considered to pose the highest risks. For emergency management officials, public health hazards, particularly pandemic influenza and risks associated with water or food were considered to be of somewhat lower priority. The methods used to analyze and rank the hazards varied considerably. In Ontario, the provincial government introduced a process called Hazard Identification and Risk Assessment (HIRA) which provides a standardized technique for assessing risks to communities and establishes a common foundation for the development of emergency plans. In other cases, cities integrated the assessment of hazards and their potential consequences into a broader risk management process which helped identify preventive and mitigation actions in addition to effective emergency response measures. It was noted by many officials that without available methods for analyzing hazards and ranking risks, smaller municipalities with fewer resources would not be able to undertake comprehensive analyses.

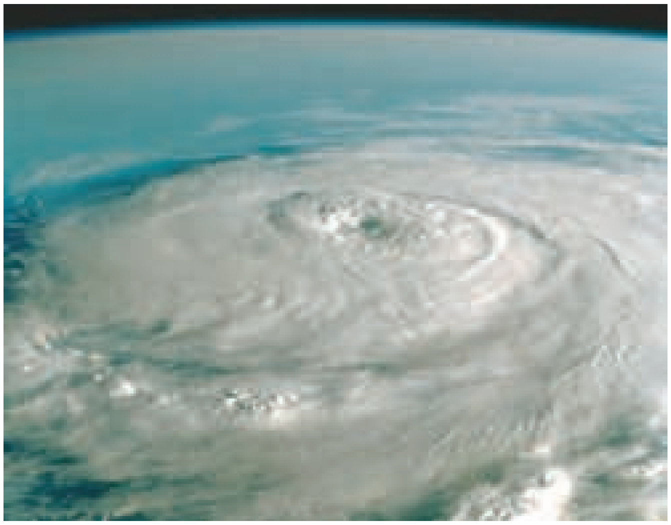
In the emergency management context, early warning implies the means by which a potential danger is detected or forecast and an alert issued (UN/ISDR, 2005a). The goal of early warning systems is to maximize the probability that people at risk will take the appropriate actions to protect themselves from a natural hazard event, whether its onset is sudden or gradual (Thomas and Mileti, 2003). Several recent international conferences have focussed on early warning systems as key strategies for reducing the health impacts of natural hazards. The Third International Conference on Early Warning in 2006, the Potsdam International Conference on Early Warning Systems for the Reduction of Natural Hazards in 1998, and the Yokohama Conference on Natural Disaster Reduction in 1994 recognized the importance of early warning systems as part of overall disaster reduction strategies. Among the many benefits of implementing an early warning system, the most important is a reduction in the loss of life and impacts on human health (O'Neill, 1997; National Health Assessment Group (NHAG), 2001; Comerford, 2005; Rego and Subbiah, 2005; World Meteorological Organization (WMO), 2005). Ancillary benefits include a reduction in impacts on individual property and on a range of economic sectors (e.g. construction, agriculture and shipping) that contribute significantly to a nation's prosperity and to the health and well-being of individuals.

Due to an increase in the power of new technologies and a decrease in their costs, early warning systems are becoming easier to implement all over the world. However, proper development and implementation are essential for recognizing the full benefits provided by such systems. The disseminated message must have a clear meaning, and the public must have adequate knowledge of the procedures to follow during a response to effectively reduce risks to health.

An "all-hazards" approach provides benefits to all segments of society by using one system to warn against multiple hazards. Canada has yet to implement an all-hazards approach to emergency management. At present, it relies on several systems that issue warnings for a number of specific natural hazards. Some communities have recognized their vulnerability to extreme weather events or natural hazards and, along with other levels of government, are taking action to reduce health risks associated with such events. Early warning systems for a range of natural hazards (e.g. heat waves, storms) have been implemented in jurisdictions across the country. A frequent problem with the systems is the weak linkage between the technical capacity to issue the warning and the capability of the public or institutions to respond effectively to it. Often, the capacity



of the warning to trigger the appropriate response by emergency management agencies, community-based organizations and the public at large is not adequate (UN/ISDR, 2005b). Efforts are under way in several communities around the world to increase public awareness of hazards and to promote individual protective measures. Canada could draw useful lessons from international experience in developing and implementing warning systems to protect health.



Satellite data, in combination with geographic information systems, are very useful for ascertaining the causes, progression, extent and impact of extreme weather events, and for discerning how natural disasters might be avoided or impacts reduced. Satellite images can help planners and emergency response teams to quickly pinpoint vulnerable locations and populations affected by natural hazards (Jedras, 2003). Weather and climate monitoring data from satellites are provided or used in this way by the Canada Centre for Remote Sensing, the Meteorological Service of Canada, the Canadian Hurricane Centre, the Canadian Wildland Fire Information Service, the Canadian Lightning Detection Network, and the Earth Observatory of the U.S. National Aeronautics and Space Administration. Current measures to identify and monitor the progression of extreme weather events in Canada that may pose health risks are highlighted below.

Heat waves

Environment Canada defines a heat wave as three or more consecutive days when the air temperature reaches at least 32°C, and issues weather advisories when a heat wave is expected to occur (Environment Canada, 2005a). A comprehensive scan of public health websites revealed that only a small number of communities in Canada presently engage in heat management activities, including heat alert systems. These systems are found largely in urban communities in Ontario and Quebec (Paszkowski, 2007). Examples of warning systems used in communities across Ontario are found in Table 3.4. Few urban communities in other regions, including the Atlantic and the Prairie provinces, have formal warning systems in place, although some communities do include heat response information and advice for vulnerable populations on their websites. However, the majority of urban communities and many small urban communities engage in "greening" activities that may contribute to a reduction in the urban heat island effect. In most cases though, heat mitigation is often not explicitly mentioned as a purpose or benefit of the existing activities (Paszkowski, 2007).

Cold waves

When unusually low winter temperatures, cold waves or winter storms are expected, weather forecasts issued by Environment Canada usually include short-term warnings to take protective measures (Environment Canada 2003e, 2005b). These forecasts are used by municipal and regional health agencies to issue local-level cold weather alerts or warnings. It would be helpful to have more accurate long-term forecasts of cold waves that communities can use to aid in preparations aimed at protecting vulnerable populations.

Table 3.4 Examples of heat warning and response activities of urban communities in Ontario

	System	Threshold	Alert	Response	Information
1	No dedicated system – mention health unit system	Not indicated	Notification to media, notice posted on website	Information about cooling options: community centres, libraries, and pools	Heat risk and protection information. Vulnerable: seniors, children, the disabled, the chronically ill
2	No dedicated system – link to health unit heat alert program	Not indicated	Notice on website; link to health unit alert program	Not indicated	Heat risk and protection information, no vulnerabilities specified
3	No dedicated system – post health unit heat alerts	Not indicated – high temperature humidex, smog	Notice on website; link to health unit	Information about cooling options: shopping centers, libraries, pools	Link to health unit information; health unit identifies vulnerabilities
4	No dedicated system – mention health unit alert system	Issuance of humidex advisory by EC	Post health unit notice on website	Air conditioned public facilities used as cooling centers. Pool hours extended.	Heat risk and protection information. Vulnerable: seniors, children, the disabled, the chronically ill
5	Mention of health unit heat alert system	Extreme heat day: humidex of 40	Issue media advisory	Extend hours for city owned pools and splash pads	No heat risk or protection information
6	No dedicated system – mention EC humidex advisory system	EC humidex advisory: Humidex of 40	None indicated	None indicated	Heat risk and protection information. Vulnerable: seniors, children, overweight or ill individuals
7	No dedicated system – mention EC humidex advisory system	EC humidex advisory: Humidex of 40	Notice on website; media release	Community centres used as cooling centres; water is distributed	Heat risk and protection information. Vulnerable: seniors, children, overweight or ill individuals
8	Humidex-based system. Three phases: *Phase 1* – heat advisory *Phase 2* – heat warning *Phase 3* – heat alert	*Phase 1* – humidex of 40, 1 day *Phase 2* – humidex of 40, > 1 day *Phase 3* – humidex of 40, > 3 days OR 45, 1 day	Notification to media; notice posted on website	*Phase 1* – issue media advisory *Phase 2* – issue media advisory with additional info *Phase 3* – control group determines response; may include cooling centres, extended pool hours, targeted outreach	Heat risk and protection information. Vulnerable: seniors, chronically ill, infants/small children, the socially isolated, individuals with limited mobility and on certain medications, those who work or exercise vigorously outdoors
9	Have a heat alert plan, no details provided	Not indicated	Notice posted on website; may notify media	Not indicated. Have an emergency response plan	No heat risk or protection information; extreme heat identified as a potential risk faced by a community
10	Humidex-based system; extreme heat alert issued by MOH	Maximum humidex: 40	Notice on website; media alert issued, may call 311 phone line for information	Air conditioned recreation facilities opened 7 days a week	Heat risk and protection information. Vulnerable: seniors, children, the frail, individuals who live alone

	System	Threshold	Alert	Response	Information
11	Humidex-based system. Three phases: *Phase 1* – heat advisory *Phase 2* – heat alert *Phase 3* – extreme heat alert	*Phase 1* – humidex of 36, 2 days *Phase 2* – Phase 1 and smog OR humidex of 40, 2 days *Phase 3* – Phase 2 and smog OR humidex of 45, 2 days	Notification on community and health unit websites; media release	Information dissemination, extension of pool hours, extension of shelter hours; community indicates presence of a heat emergency plan	Heat risk and protection information. Vulnerable: seniors, the socially isolated, those with low income, those with chronic/ pre-existing illnesses (including mental illness), children, the homeless
12	Humidex-based system	Humidex of 40, 1 day OR 36, 3 days; other factors may be considered	Alerts issued by the public health unit; no further details	Not indicated. Have an emergency response plan	Heat risk and protection information (from the health unit). Vulnerable: seniors, young children, work or exercise vigorously outdoors, have chronic heart/lung conditions, individuals on certain medications, have risk factors like obesity, fever, dehydration, poor circulation, sunburn
13	Temperature or humidex based system, 3 levels: *Level 1* – heat alert *Level 2* – heat warning *Level 3* – heat emergency	*Level 1* – 36, 2 days *Level 2* – Level 1 and smog OR 40, 2 days *Level 3* – Level 1 and situational factors OR Level 2 and smog OR 45, 2 days	Notification posted on website; notify public via media releases	*Level 1* – information disseminated, air conditioned locations promoted *Level 2* – level 1 actions plus cooling centres open to vulnerables *Level 3* – level 2 actions plus "municipal control group" determines further action	Heat risk and protection information. Vulnerable: children, unacclimatized persons, seniors, persons with chronic medical conditions
14	Humidex-based system, 3 phases: *Phase 1* – heat alert *Phase 2* – heat warning *Phase 3* – heat emergency	*Phase 1* – humidex of 36, 2 days *Phase 2* – humidex of 40, 2 days *Phase 3* – humidex of 45+, situational factors	Public is notified via website, notification of media, notification to service providers	Information dissemination, extension of pool hours, extension of shelter hours; community indicates presence of a heat emergency plan, no further details	Heat risk and protection information. Vulnerable: the isolated, homeless, those on certain medica-tions, those with health conditions (heart/kidney disease, respiratory problems), seniors, young children, the unacclimatized – specific info for service providers to the homeless
15	Synoptic classification system, 2 phases: *Phase 1* – heat alert *Phase 2* – extreme heat alert	*Phase 1* – 0.65 probability of excess death *Phase 2* – 0.90 probability of excess death	Public is notified via website, notification of media, notification to service providers	*Phase 1* – Red Cross operates a phone line, information dissemi-nated, water distributed, trans-portation provided as necessary, extended hours at shelters *Phase 2* – All phase 1 steps plus 5 cooling centres opened, extended pool hours	Heat risk and protection information. Vulnerable: seniors, individuals with chronic illnesses or impaired mobility or on certain medications, infants/preschool children, people who work/exercise outdoors, homeless or marginally housed persons, the overweight; specifics on children and persons on medication

Source: Paszkowski, 2007.

Thunder and lightning

When there is a risk of severe storms, including thunderstorms, Environment Canada issues severe weather warnings. Lightning strikes in Canada are monitored by an automated Lightning Detection Network (Environment Canada, 2003b). In combination with weather (Doppler) radar systems, this enables high-risk areas for thunderstorms and lightning flashes ("hot spots") to be identified and mapped as thunderstorms progress (Environment Canada, 2003a, 2003b, 2003c, 2007c). Often triggered by lightning strikes, the threat of wildfires can pose an ongoing risk to communities, particularly during summer months. Daily updated maps and satellite images of wildfire risk and wildfire hot spots across Canada are prepared and made accessible on the Internet by the Canadian Forest Service (NRCan, 2006a). GeoEye Incorporated also frequently publishes satellite images of wildfires and their air pollution plumes.

Floods

There are several flood forecasting centres in communities and provinces across Canada. (e.g. Alberta, British Columbia, Great Lakes, Kennebecasis River, Saint John River). Each system reflects the characteristics of the community that it serves to protect through variations in data acquisition, allocated resources, information services, administrators and partners, education and outreach activities, and nomenclature of event (e.g. High Water Advisory versus Flood Warning). Most systems integrate information on factors affecting flooding, such as snow conditions, temperature, precipitation patterns, water level and stream flow conditions. This information is provided by public agencies in Canada and in the U.S., as well as by private enterprises. The flood warnings are distributed most commonly to emergency measures organizations, local government officials, pertinent provincial and federal government officials and the news media (Environment Canada, 2007e).

Tornadoes

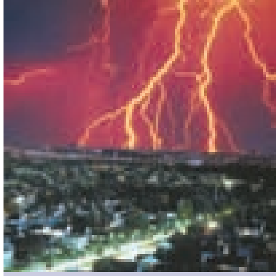
The identification and forecasting of tornadoes relies on weather radar surveillance systems and on satellite images; this allows only short-term forecasts (Marsh et al., 2007). Presently, available weather and climate models are not sophisticated enough to be used for simulating and accurately predicting tornadoes, which tend to be localized. Nevertheless, the models can be used to simulate the conditions under which such events occur.

Hurricanes

Since the 1970s, satellite data and images have been used to forecast the development and movement of hurricane-force storms in the Atlantic (Böttger et al., 1975). Since then, improvements in satellite instrumentation, monitoring instruments dropped from planes, weather radar equipment, computer programs, communications technology and international cooperation have greatly improved the accuracy of hurricane forecasts and their availability to the public. The Canadian Hurricane Centre of Environment Canada in Dartmouth, Nova Scotia, used these and other means to provide early warnings of Hurricane Juan and other tropical storms that have threatened the inhabitants of the Canadian East Coast. Among the improvements made since Hurricane Juan is a new and more secure building for the Atlantic Storm Prediction Centre (Environment Canada, 2006a, 2006b).

Landslides

For some populated high-risk areas such as the Saguenay-Lac-Saint Jean region, the shores of the lower St. Lawrence River in Quebec, and parts of southern British Columbia, government agencies have established risk maps and risk zoning guides to help protect people and property from landslides (Lajoie, 1974; Miles & Associates Ltd., 2001; Evans et al., 2002; Bilodeau et al., 2005; Rouleau et al., 2006).



3.6.2.4 Response, recovery and resilience

In the past decade, many regions and large cities in North America have fallen victim to large-scale disasters and emergencies. This has tested existing capacity to protect the lives and health and well-being of citizens, and has exposed weaknesses in the ability of governments to respond to such events and support the recovery of communities. As a result, several investigations have been conducted to examine preparedness for a range of large-scale emergencies and disasters. One such investigation was undertaken in Canada in mid-2000 by the Standing Senate Committee on National Security and Defence, with the purpose of determining where federal government leadership was most needed "to ensure that the nation provided its citizens with the best protection possible at a reasonable cost" (Standing Senate Committee on National Security and Defence, 2004). Findings from this study, which focussed on first responders, were based on extensive interviews with key emergency preparedness officials at all levels, field visits and survey results. Key findings from this study are presented below.

- Larger cities are generally better prepared than smaller communities to deal with emergency or disaster situations.
- More than half of medium and large cities are able to respond effectively to an emergency, according to interviewed officials.
- Few smaller communities are able to respond effectively to an emergency, according to interviewed officials.
- The major capacity issues identified were related to communications and coordination among response agencies, communications with the public, and access to critical supplies and professional training.
- There was a strong desire for better linkages on emergency preparedness matters among municipal, provincial and federal governments, and for the large cities, between municipal and federal governments.
- A national plan for critical public health emergencies should be developed and municipalities should be fully informed about the plan.

Further evidence suggests that, overall, larger cities are generally better prepared to deal with emergency or disaster situations than small communities. A survey of emergency management officials in eight large Canadian cities in 2005 revealed that almost all medium and large communities had designated a full-time official to be responsible for emergency preparedness, and officials in most large cities felt able to effectively respond to an emergency (Health Canada, 2005c). However, in most cases, the development of response capabilities has used an increasing share of the municipal budget, resulting in fewer funds for other municipal functions. For many of the communities very little funding has been provided for first responders from higher levels of government (e.g. provincial or federal). As well, many activities related to preparedness training have been constrained by tight municipal budgets (Health Canada, 2005a).

Because many Canadians exposed to natural hazards live in small communities and regions outside metropolitan areas, efforts are needed to increase the capacity to manage hazards present in these areas. Table-top simulation exercises in two small communities in New Brunswick and Newfoundland and Labrador to test local capacity to respond to a storm surge provided insights into the kind of support and improvements that are needed to manage future emergencies (Health

Storm surge table-top simulation excercises in Shediac, Newfoundland and Labrador, 2005

Chapter 3

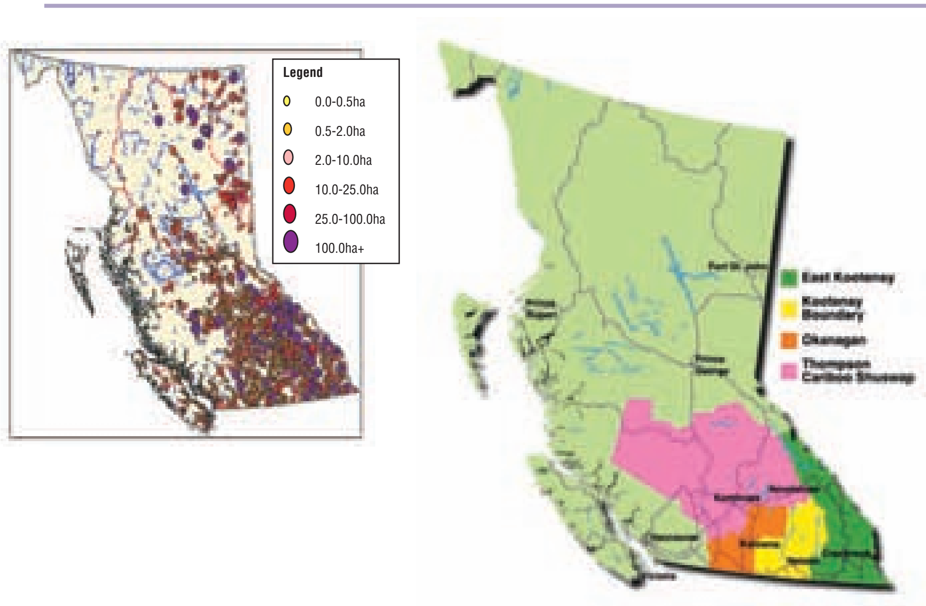
Canada, 2007c). While there is capacity in small communities to deal with events of a smaller scale and duration, the kinds of hazards that extreme weather events can trigger may often overwhelm local services and, in some situations, regional capacity. Both exercises found benefits in examining how authorities across municipal boundaries, sectors and agencies, as well as across different levels of government, coordinate and collaborate in responding to large-scale emergencies and identify ways to improve preparedness (Health Canada, 2007c).

Case study: Forest fires near Kelowna, British Columbia, 2003

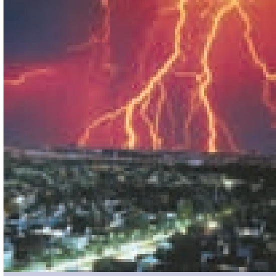
During 2003, the driest spring and summer since 1929 occurred in the southern interior of British Columbia (B.C). The previous year, local, regional and provincial firefighting and emergency plans had been revised to better deal with "interface" fires in areas where buildings had been constructed in wildland environments with flammable vegetation such as grasses, bushes and trees (Government of British Columbia, 2002). However, these plans had underestimated the possibility of a record drought producing huge amounts of dry fuel that might combine with high winds to produce large forest fires. This combination of environmental factors enabled large forest fires which were uncontrollable to develop. Moreover, the emergency plans had not included any provisions for dealing with the aftermath of the physical, health and social consequences of large forest fires.

That summer, over 266,000 hectares of forest in British Columbia were swept by more than 2,500 wildfires. They cost the lives of three pilots engaged in fire fighting, forced the evacuation of more than 45,000 people, destroyed at least 350 homes and businesses, damaged transportation and communications infrastructure, and required the deployment of about 6,000 firefighters; total costs amounted to about $700 million (Anderson et al., 2003; Filmon et al., 2004). Among the wildfire outbreaks with the worst effects on community health and well-being was the Okanagan Mountain Park fire near Kelowna (figure 3.9). This fire started on August 16, 2003, spread rapidly because of strong winds, and required tremendous efforts to bring it under control. The fire invaded the outskirts of Kelowna, where it burned 238 homes and forced the temporary evacuation of about 5,000 residents (Anderson et al., 2003).

Figure 3.9 Forest fires in British Columbia in 2003 (left), and Interior Health Authority administrative districts most affected by the fires (right)



Sources: Filmon et al., 2004; B.C. Interior Health Authority, 2007.



In the Thompson Cariboo Shuswap Health Service Area, patients had to be evacuated over distances of up to 55 kilometres, and emergency accommodations for these patients had to be made available in public and private health care facilities in other regions. In the East Kootenay Health Service Area, patients also had to be transferred to emergency accommodations. This early experience was useful when about 100 patients in a private care facility in Kelowna had to be evacuated to other towns. The evacuation and care of hospital patients and residents of chronic care facilities demanded significant efforts by the health authorities, as well as ambulance services managers and staff, some of whom had also lost their homes to the fire (Anderson et al., 2003; B.C. Interior Health Authority, 2003).

Non-governmental organizations, such as the Canadian Red Cross, the Salvation Army, the Mennonite Disaster Relief Fund and others also provided much needed help to evacuees and other people affected by the wildfire disasters. In October 2003, the federal government provided $100 million to the government of British Columbia for disaster relief.

In November 2003, the B.C. Ministry of Health commissioned a review of the performance of health services during the wildfire disasters of August 2003. The report was completed in January 2004. On the whole, it spoke well of their performance; nevertheless, it included 21 recommendations for improvements (Lynch, 2004). The Government of British Columbia also established a 2003 Firestorm Provincial Review Team to recommend improvements to the provincial emergency program, and to local and regional community emergency plans. It focussed mainly on the performance of provincial agencies responsible for forest management, forest fire prevention and control, emergency services and evacuations, and post-emergency recovery, and made many recommendations for improvement (Filmon et al., 2004). In 2006, the British Columbia Forest Service produced a revised strategy to better cope with future wildfires (Foglam, 2006). The lessons learned by emergency and health services during the 2003 wildfire disasters in British Columbia (e.g. as summarized by Filmon et al. (2004) and Lynch (2004)) can be applied to other regions of Canada at risk from forest or wildfires.

Effective adaptation through emergency management activities increases individual and community resilience to disasters. Resilience refers to the capacity of a system, community or society to persevere, recuperate or change in reaction to an extreme weather event or disaster, in order to reach and maintain an acceptable level of functioning (PSEPC, 2005a). Increasing resilience requires an all-hazards approach and an “all-vulnerabilities” approach that involves identifying and addressing all key aspects of vulnerability (Henstra et al., 2004), including vulnerabilities of specific populations. Resilience also depends on the health of the population; healthier people adapt better to health risks associated with climatic and other environmental changes (McMichael, 2003).

To determine if individuals and communities are resilient to natural hazards, it is necessary to better document and understand the long-term effects of natural disasters on important determinants of health such as employment, health services, social networks and physical environment (e.g., water quality). No multi-disciplinary studies have been undertaken in Canada to address these research needs for any of the natural hazards of concern. This type of research would help identify whether Canadians will be able to cope with the expected increase in frequency and intensity of many natural hazards due to climate change.

3.6.3 Barriers and Opportunities for Adaptation

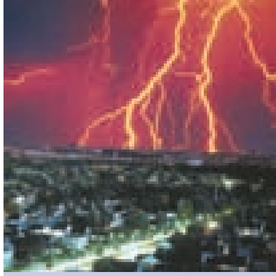
Studies carried out as part of the Canadian Natural Hazards Assessment Project indicated that despite some improvements in planning and response capacity, Canada has become more vulnerable to natural hazards because of population growth, urbanization, an aging population and infrastructure, increasing environmental degradation and over-reliance on technologies (Environment Canada, 2003d). Similarly, a study of fatalities and increasing economic losses due to weather and climate-related extremes during the 20th century in the U.S. indicated that these were due primarily to factors contributing to increased vulnerability—population growth in large urban areas, flood plains and coastal zones, more property subject to damage, higher property values, and other societal changes (Kunkel et al., 1999). As discussed in Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada, concerns have been raised about current efforts by all levels of government to reduce health risks associated with natural hazards in Canada. Gaps in efforts to mitigate, plan, and prepare for the impacts of natural hazards contribute to the vulnerability of communities and individual Canadians. Existing barriers to making strides in emergency management efforts in Canada to improve adaptation to health risks from natural hazards are discussed in the next section, as are opportunities for taking needed actions.

3.6.3.1 Barriers

The development and implementation of efficient and effective strategies, policies and measures to reduce current and future vulnerability to climate change-related health impacts face certain barriers. Having the capacity to adapt does not necessarily ensure that individual Canadians or health and emergency management authorities will take the measures needed to reduce risks from natural hazards; this is because societal values, perceptions and levels of cognition are all important in shaping adaptive behaviours (Schneider, 2004). Most adaptive decisions are made by individuals in government, industry and within communities so that they can preserve their interests in areas of immediate concern, including their health, the health of their families, and the value of their assets. Investments and measures to mitigate impacts from natural hazards are often only made after a disaster has taken place in an effort to reduce the risks of similar impacts in the future.

Barriers to adaptation may also arise when there are technological challenges associated with the proposed measures. For example, due to the short timeframe for detection and warning, many extreme weather events, such as tornadoes, allow little time to prepare or to seek shelter, hence morbidity and mortality is proportionally higher compared with some other types of disasters (Greenough et al., 2001). The effects of Hurricane Juan in Nova Scotia in September 2003 also showed that some of the damage caused by severe storms such as hurricanes mays be unavoidable, although emergency management measures for hurricanes envisage both damage prevention and recovery.

Constraints on adaptations at the community level may also include the environmental implications of proposed actions (e.g. stormwalls), economic costs, lack of training and institutional capacity (particularly for small communities), as well as social and legal acceptability (Ebi et al., 2006). The resources available for disaster mitigation may be shared or in competition with those for a variety of public health issues (McMichael, 2003). Deliberations over the distribution of costs for adaptation measures between public and private agencies can be an important barrier to action. Any potential return on investments to mitigate natural hazards is realized only after a disaster is averted, whereas the investment costs are immediate and potentially



significant. There may be little economic incentive for a community to invest in prevention measures because most of the financial costs of recovery are paid by insurers and higher-level governments.

Perceptions, attitudes and knowledge of the roles of decision makers in addressing climate change health risks are important elements in the process of adaptation and can constitute important barriers to action. Interest in disaster mitigation is sporadic, and citizens generally perceive a low probability of loss from such events; this is because specific disasters have occured infrequently and rarely in the same locale within a short time span. However, with an increased frequency of extreme weather events, public perceptions may change regarding the need for disaster mitigation investments. These and other barriers to adaptation are discussed in Chapter 6, Health Impacts of Climate Change in Quebec, and Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada.

Case study: Lessons from the Quebec Saguenay flood, 1996

Photo Credits: Canada Centre for Remote Sensing, Natural Resources Canada, 1996

An official inquiry into the causes and consequences of the 1996 Saguenay flood found a "culture of denial" among residents and municipal and regional governments; all disregarded the possibility of serious flooding (Conseil pour la prévention et la gestion des sinistres et des crises (CPGSC), 1998). This situation was probably not unique to the Saguenay region. Another study found that, in communities along the upper St. Lawrence River, there had been little attention given to flood prevention; flood plain occupancy had continued and in some cases had even greatly increased from the 1970s on, with urban expansion appearing to be unrestricted by flood plain designations. Reliance on government indemnity payments as a kind of insurance may have encouraged this trend (Doyon and Côté, 2006). After the Saguenay flood, recommendations were made for the creation of a "public safety culture": (1) strengthening and integrating municipal and public safety planning and cooperation; (2) providing greater support for Securité publique Québec so that more staff for public safety would be available, along with better training for them and backup personnel; (3) increasing awareness among individuals and organizations about their responsibilities for collective safety; and (4) supporting applied research through a special institute that would focus on training, research and action in the area of public safety (CPGSC, 1998).

3.6.3.2 Opportunities

There is sufficient knowledge about the risks and impacts of natural hazards to take proactive measures to protect health. For example, a suite of tools and technologies such as geological hazard surveys, aerial photographs, satellite images, mathematical modelling and geographic information systems can be used to identify and map geomorphological hazards, such as areas prone to avalanche, landslide or rockfall. Terrain stability mapping can be legislated, and guidelines can be provided for its implementation (Resources Information Standards Committee (RISC), 1997; Evans et al., 2002; Association of Professional Engineers and Geoscientists of BC (APEGBC), 2006; NRCan, 2006a; Klamath Resource Information System (KRIS), 2007; McLaren, 2007). Under the Aboriginal and Northern Community Action Program, studies

are being funded to assess the implications of climate change for northern communities both above and below the Polar Circle. The purpose of these studies is to ensure the health and safety of northern residents, the sustainable development of communities, and to improve the ability to manage the risks posed by natural hazards related to climate change (Indian and Northern Affairs Canada (INAC), 2006). As well, in some cases, stabilization measures can be taken to reduce the likelihood of property damage or loss, and of injuries or deaths resulting from landslides (Chatwin et al., 1994; Government of Alberta, 2005). This can include the installation of stabilizing or protective structures on slopes, the planting of bushes or trees on slopes, the protection of existing forests, planned releases of hazardous snow burdens, and avoidance of unstable snow masses or unstable ground.

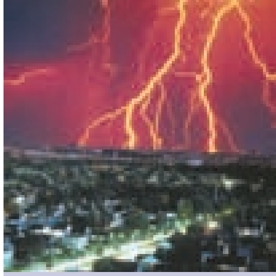
A floodway was built in 1960 with $63.2 million in public funds to redirect occasional excess water from the Red River around the city of Winnipeg. Although expensive to build and even more to modify, it has saved an estimated $8 billion in potential damage and recovery costs (PSC, 2008).

Many adaptation options are accessible and affordable. For example, buildings can be protected from lightning at limited cost according to a National Standard of Canada for Lightning Protection Systems (CAN/CSA-B72-M87) (International Association of Electrical Inspectors (IAEI), 2000). The effectiveness of such systems was shown in a 10-year survey conducted in Ontario during the 1930s. During that time, 10,079 unprotected structures were damaged by fires caused by lightning, but only 60 such fires occurred in protected buildings, and in most of these the lightning conductors had not been installed properly (Aulich et al., 2001).

Canada's National Disaster Mitigation Strategy recognizes the need for climate change adaptation activities to reduce the risks of disasters (PSC, 2008). Smart land-use planning and development can prevent much harm and property loss from natural hazards. New information about the impacts of natural hazards on health can facilitate the development of needed risk management strategies and can be incorporated, or mainstreamed, into a range of professional practices (e.g. land-use planning, public health and medical practices, environmental management). The concept of mainstreaming climate risks describes processes that bring explicit consideration of climate and related risks into decision making processes. This concept is key to improving the basis upon which decisions are made by institutions and individuals regarding the risks they face today and in the future.

Health studies concerning specific individual vulnerabilities are also yielding knowledge that can inform adaptation. For example, results of laboratory and epidemiologic studies indicate that humans have a well defined "temperature comfort and tolerance range." Temperature-related vulnerability changes with age, and is affected by gender, state of health, degree of acclimatization to seasonal changes, and socio-economic factors. This makes it possible to identify the most vulnerable population groups locally and regionally, to direct protective measures toward them, and to improve the accuracy of mathematical modelling (projections) of the impacts of future climates on health. Professionals in many fields need to take into account new knowledge about climate and its impacts in order to improve current systems, protect growing populations, and communicate with researchers about additional information and data required to improve risk management practices.

Chapter 3



3.7 KNOWLEDGE GAPS

Several knowledge gaps have been identified with regards to natural hazards, their implications for human health, and the effects of climate change on the exposure of Canadians to these hazards. Addressing the following knowledge gaps will be crucial to the development of effective public health and emergency management measures to protect Canadians from increased health risks associated with climate change:

- the risks to health from specific natural hazards (e.g. floods);
- data on and indicators of health impacts from natural hazards in Canada, including improved reporting of the impacts of natural hazards on health;
- the social, psychological and mental health impacts of natural hazards, so that communities and health care providers will be able to better anticipate disasters, prepare vulnerable populations and develop adequate programs to address their effects;
- the role of health services in the mitigation of natural hazards and in aiding the victims of natural disasters;
- the effectiveness of warning and prevention systems;
- the characteristics or qualities that make specific populations more vulnerable to climate change and health impacts arising from more frequent and severe extreme weather events, and the distribution of such vulnerable groups within Canada; and
- the effectiveness of messages and outreach strategies for changing individual behaviours to reduce health risks (e.g. appropriate messaging during emergency situations) and of interventions by public health officials.

3.8 CONCLUSIONS AND RECOMMENDATIONS

3.8.1 Conclusions

Natural hazards pose diverse risks of varying magnitude to the health of Canadians in all regions of the country. Drought, severe storms, extreme heat and cold events, storm surges, floods and other climate-related natural hazards can affect health and well-being by causing increased risk of injuries, illnesses, stress-related disorders and, in extreme cases, death. Natural hazards can also impact health indirectly by causing local or regional economic disruptions, interruption in health care services, infrastructure damage and population displacement. During the 1990s in Canada, natural hazards caused approximately 170 deaths and 1,000 injuries, and affected 700,000 people. Extreme weather events, such as the 1998 Ice Storm that affected eastern Canada, Hurricane Juan that impacted Atlantic Canada in 2003, and recent wildfires and floods across the country are examples of natural hazards that have had important impacts on the economies and health and well-being of people living in the affected communities. Although mortality in Canada attributed to natural disasters has decreased in the past several decades, injuries and economic costs have risen.

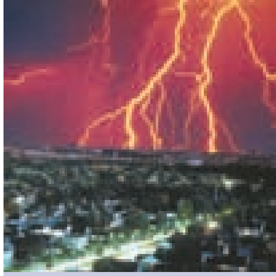
The full scope of the impacts of natural hazards on health is not well understood and documented. Impacts tend to be under-reported because only events of a certain scope and size are taken into account in existing studies and in currently available databases. Comprehensive health data needs to be collected during and after extreme weather events to enable the study of population vulnerabilities. Given the diversity across Canadian regions, it is not possible to apply the findings of a few studies of a specific disaster or extreme weather event to the entire population. Increased funding and new methodological approaches are needed to broaden research in this area and engage the various disciplines required to conduct such research.

Extreme weather events can have significant psychological and social impacts on people, and effects can be felt long after emergency response personnel have left the affected communities. Recent studies have shown that the longer an event disrupts a person's life, the greater the level of stress experienced; as a result, a person's ability to cope may become diminished. Some research exists, mostly outside Canada, on the psychological and social impacts of sudden and devastating weather events on people. More attention should be paid in future investigations to long-term health effects on individuals and on communities of natural disasters of varying magnitude.

Certain populations in Canada are at greater risk from the health impacts of natural hazards. People with low incomes may find it more difficult to cope with the stressful effects of disasters because they may already be experiencing chronic stress due to inadequate housing and nutrition, and because they cannot afford the cost of needed support such as mental health professionals, medications or other aids, and repairs or replacement of belongings. Seniors are one of the highest-risk groups because they may be socially isolated and may have fewer economic resources on which to rely. Some seniors may also lack the required mobility to move out of harm's way, thus increasing the likelihood of physical stress and trauma. Children, like seniors, are considered one of the most vulnerable groups in weather-related disasters.

Climate change will influence a broad range of natural hazards to which Canadians and communities from coast to coast are already exposed. Warming of the climate system is "unequivocal" and the risks of health-impacting natural hazards will increase. Around the globe and in North America, the occurrence of hazardous events, except cold days, that impact on health is expected to increase. More hot days and more frequent and intense heat waves are expected. Cities that currently experience heat waves in Canada (such as Montreal, Toronto, Hamilton, Winnipeg, Saskatoon and Calgary) can expect the challenge of an increasing number, intensity and duration of these events, posing serious risks to health to vulnerable populations. More frequent and intense heavy precipitation events and hurricanes, leading to increased risks from flooding, are expected in various regions of Canada, as are more droughts and wildfires.

There is a strong foundation of emergency management in Canada to build upon to adapt to future risks from natural hazards related to climate change. Although some communities and provincial and federal authorities are taking actions to reduce the risks, greater actions are required by others to safeguard Canadians from the risks. Recent investments in emergency management activities have generally focussed on enhancing warnings, mapping hazards or strengthening response activities; while these are necessary activities, there has been limited investment in prevention and mitigation efforts across the country. Many health risks are heightened by cumulative environmental and social conditions that can increase the impacts of events and lead to disasters; in many cases communities are not prepared for a change in the magnitude of events or in the increasing occurrence of different events in quick succession. The rising costs of natural hazards and disasters may well act as drivers for investments in mitigation but perceptions of limited threats from these events continue to act as a barrier to action.



As well, there are institutional challenges involved in protecting Canadians from natural hazards. In Canada, intergovernmental collaboration on emergency management activities is essential for the development and implementation of effective policies to protect Canadians. While responsibility for emergency management is largely delegated to municipal governments, mechanisms for collaboration and coordination across all levels of government and with the voluntary sector need to be enhanced in order to fully benefit from the capacities present in society.

Because disasters occur relatively infrequently, interest in disaster prevention can be sporadic and short-lived, particularly if citizens generally perceive a low probability of loss from such events. The post-disaster opportunity and policy window for improving preventive measures is usually overtaken by the primary goal of returning the affected community to "normal" as quickly as possible. The successful management of risks from many types of natural hazards can require long-term commitment and significant public and private investments. Awareness of the risks by the population is needed for such actions to be taken. The monitoring and reporting of impacts from the full range of natural hazards is essential to inform decisions on priority areas for action. To this end, climate modelling can be used to predict changes in conditions that may affect the risk to populations and help in identifying potential hazards and vulnerabilities.

3.8.2 Recommendations

Through public and private institutions, Canadians have a wide range of adaptive capabilities, with a number of notable successes and failures in mitigating, preparing for, responding to and recovering from extreme weather events. In most cases, improvements in emergency management systems have been implemented in response to disasters or large scale events; there is now a need to look ahead to the future and take more proactive measures to mitigate and prepare for the expected increase in the frequency and severity of extreme weather events. Knowledge exchange and cooperation in policy and planning among the public health, emergency management and climate change hazards communities should be strengthened. Innovative efforts are needed to work across these areas of responsibility and engage other sectors in reducing health risks. For example, the appropriate design of infrastructure and transportation systems can reduce health vulnerabilities while enhancing resiliency to natural hazards and environmental sustainability. There are many opportunities for collaborative work across levels of government, through the dissemination of best practices, and the integration of warning systems. Priority areas of action to improve the management of health risks from extreme weather events and disasters and enhance resilience include:

Renewing and strengthening infrastructure

Large portions of Canada's infrastructure are slated for service renewal and expansion in many cities and smaller communities. The Building Canada infrastructure plan provides $33 billion from 2007–2014 to help meet infrastructure needs across Canada. Announced in 2007, it provides a framework for the federal government to collaborate with provinces, territories and municipalities to take actions to improve infrastructure in Canada. It is imperative that new or upgraded infrastructure is able to withstand the more frequent and intense natural hazards expected in the coming decades as the climate continues to change. Opportunities exist to make progress in this regard: they include the collaboration between the Canadian Council of Professional Engineers and Natural Resources Canada to upgrade building and design codes and standards to reflect changing climatic conditions. Planners and government officials need to use this information and adopt a long-term outlook in their decision making process to ensure that individuals and their communities are protected.

Investing in knowledge to reduce uncertainty for decision making

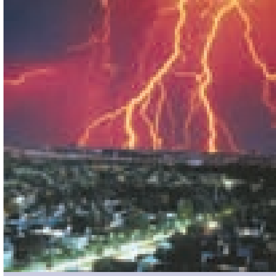
Canadian research on natural hazards, existing vulnerabilities and health impacts will help reduce the uncertainties in this area, and highlight the need for immediate actions. More knowledge of climate change risks and effects on health is required by public health and emergency management

professionals, and increased attention needs to be paid to research on the adaptive capacity of health and social services organizations to plan for and manage extreme weather events and natural hazards. This chapter builds on the results of the Canadian Natural Hazards Assessment Project—a joint effort of the Meteorological Service of Canada, Public Safety and Emergency Preparedness Canada, and the Institute for Catastrophic Loss Reduction—which assessed natural hazards in Canada, identified existing vulnerabilities, and sought to inform policy making. Research and advocacy within the emergency management community is becoming better coordinated through the Canadian Risk and Hazards Network (CRHNet), which was formed in 2003 to promote disaster risk reduction and management in Canada. This network provides the opportunity to continue building research capacity in Canada and increase the integration of research results into policy development and planning at all levels of government.

Increasing Canadians' preparedness
All levels of government need to increase efforts to inform and empower individual Canadians so that they can adequately protect themselves from existing risks. Canadians do not yet see the need to take personal action to protect their health from the hazards that will change with the climate. There is a need to increase awareness of the risks and knowledge of the measures that can be taken in order to reduce exposure to them. The development of a culture of disaster preparedness and mitigation, as advocated by the Nicolet Commission which examined societal responses to the 1998 Ice Storm (Government of Quebec, 1999), is an important part of adapting to climate change. It is also important to ensure that Canadians have reasonable access to preparedness information and response and recovery services. This is a common need in communities across Canada, however, rural and remote communities face particular challenges which need to be addressed.

National leadership and advancing prevention
Protecting Canadians and their communities from natural hazards associated with a changing climate requires coordinated efforts to prevent and mitigate risks. Implementing mitigation actions, with a focus on reducing the human health impacts resulting from natural hazards, requires a sustained effort from a wide range of public-and private-sector actors and organizations. Collaboration at all levels of government is critical to ensure that such activities become a key component of emergency management in Canada. The role of volunteers in protecting communities from natural hazards must be more fully integrated into emergency management activities. Important considerations in this regard include bolstering the volunteer infrastructure and capacity to cope with large-scale and multiple events, the training of new volunteers and addressing protection and compensation issues. Collaborative intergovernmental approaches that are developing in other policy fields, such as health care and the environment, may offer encouraging examples and provide useful opportunities for knowledge sharing and program development. Integration across relevant fields is essential. Lessons learned from past successes will help Canadians plan for future risks associated with climate change.

Risks to the health of Canadians from natural hazards and extreme weather events will increase as the climate continues to change and as other factors contribute to vulnerability. To protect all Canadians, in particular those most vulnerable to the health impacts, a comprehensive commitment is required to guide collaborations in order to improve emergency management activities, from mitigation to community recovery, across Canada.



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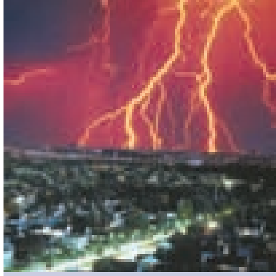

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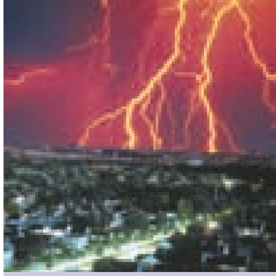

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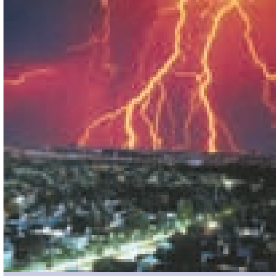

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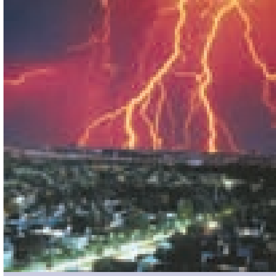

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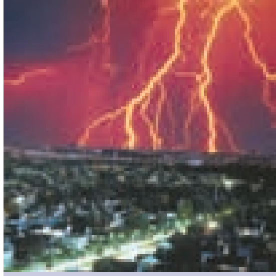

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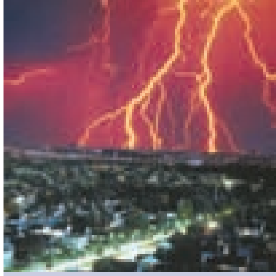

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Chapter 4

Air Quality, Climate Change and Health

Serge Lamy

Véronique Bouchet

Contributors:
Kathleen Buset
Sophie Cousineau
Barry Jessiman
Branka Jovic
Stan Judek
Cheryl Khoury
Tom Kosatsky
Eric Litvak
Radenko Pavlovic
Nedka Pentcheva
Dave Stieb

Chapter 4

CONTENTS

4.1 INTRODUCTION

This chapter focuses on the potential impact of climate change on air quality and related health impacts in Canada. The chapter begins by providing a summary of the potential adverse health impacts of air pollution with a focus on ground-level ozone (O_3) and particulate matter (PM), and of extreme heat, including heat waves. An examination of potential additive or synergistic effects between extreme heat and air pollution was also conducted because heat may modify the nature of potential air pollution-related health impacts. Studies examining seasonal air pollution effects, air pollution effects among cities with different climates and different temperatures, as well as studies of population responses to extreme heat events are reviewed. (See Annex 1 for more information on the literature search methodology.) The literature review covered sources to 2006 except for the citing of a few authoritative sources that were published subsequent to that (e.g. the 2007 IPCC Assessment).

The chapter also examines how an increase in mean temperature (of 4°C) due to climate change might impact summer time levels of O_3 and PM in Canada. Two scenarios were considered: one examining the independent effect of increased temperature on air quality and the second examining the effect of both increased temperature and the potential contribution of changing natural emissions of volatile organic compounds (VOCs) to the formation of these pollutants. The results of these two modelling scenarios were then compared with a reference year (2002). Other potential effects of a warmer climate on anthropogenic emissions, climatology (e.g. humidity, wind) and natural constituents of the atmosphere affecting air quality, such as pollen and spores, were not considered.

Lastly, the potential impacts of modelled changes in O_3 and PM concentrations on human health were investigated. Changes in air pollution-related morbidity and mortality were estimated according to each scenario and their associated costs were calculated. The chapter reviews some measures used to manage air pollution-related risks in Canada and concludes by offering recommendations for future research efforts.

4.2 HEALTH IMPACTS OF AIR POLLUTION AND EXTREME HEAT

Air pollution exposure, both acute and chronic, is associated with a number of adverse health impacts which have been evaluated in many formal risk assessments (e.g Working Group on Air Quality Objectives and Guidelines (WGAQOG), 1999a, 1999b; World Health Organization (WHO), 2003; U.S. Environmental Protection Agency (U.S. EPA), 2005). The research available to the scientific community which describes these effects is voluminous and addresses worldwide issues as well as specific Canadian situations and mortality associations (Burnett et al., 2000; Goldberg et al., 2000; Krewski et al., 2000; Goldberg et al., 2001a, 2001b, 2001c, 2001d; Pope et al., 2002; Burnett and Goldberg, 2003; Vedal et al., 2003; Villeneuve et al., 2003; Finkelstein et al., 2004; Jerrett et al., 2004; Pope et al., 2004). Extreme heat and heat waves have also been implicated as a growing health concern. For example, large numbers of heat wave-related illnesses and deaths occurred in the U.S. and Europe in the 1990s (Ballester et al., 1997; Dematte et al., 1998; Semenza et al., 1999; Keatinge et al., 2000; McGeehin and Mirabelli, 2001; Curriero et al., 2002; Diaz et al., 2002; Hajat et al., 2002; Naughton et al., 2002; Koutsavlis and Kosatsky, 2003). In August 2003, the extreme heat wave that struck Europe was implicated in many thousands of deaths and contributed to public concern about the potential health impacts related to climate change (Ledrans and Isnard, 2003; Diaz et al., 2004; Koppe et al., 2004; Kovats et al., 2004; Johnson et al., 2005; Carcaillon et al., 2006).

The Intergovernmental Panel on Climate Change (IPCC) projects a continued rise of atmospheric greenhouse gases (GHGs) during the next century, resulting in further warming of the climate (IPCC, 2007a). Climate change has been observed through recent increases in global average air and ocean temperatures, widespread melting of snow and ice, and the rising global average sea level (IPCC, 2007a). It is very likely that such warming will result in more frequent heat waves. It may affect levels of air pollution exposure by changing local and regional weather conditions and by affecting both natural and anthropogenic sources of air pollutant emissions (Watson et al., 1998; IPCC, 2007b; U.K. Department for Environment, Food and Rural Affairs (DEFRA), 2005). Climate change may also result in changes in patterns of activity and associated air pollution exposures. The independent effects of heat, ground-level O_3 and particulate matter on human health are described below. This is followed by a discussion of the potential synergistic health effects of extreme heat and air pollution.

4.2.1 Health Impacts of Extreme Heat

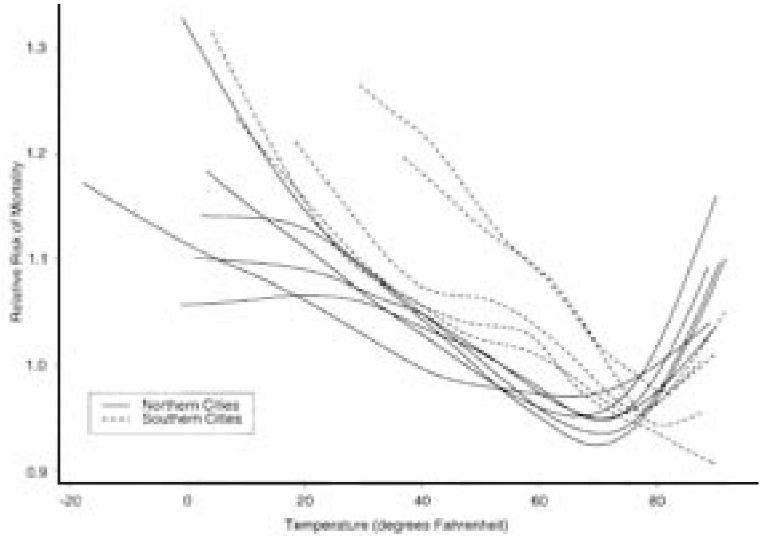
Beyond a narrow comfortable zone ("thermoneutral zone") in which body heat loss and heat gain are equal, exposure to the heat or cold can cause illness (morbidity) and eventually death (mortality). The body regulates environmental heat exchange by controlling the metabolic rate in the internal organs, blood flow through the skin, and shivering or perspiration (Rowell, 1983; Dinarello and Gefland, 2001). Normal adaptation to heat stress involves increased cardiac output and a relaxation of the blood vessels in the skin to increase blood flow from the core to the surface of the body. The production of sweat cools the body through evaporation (Bouchama and Knochel, 2002), although it is less efficient under humid conditions.

Certain people may be unable to increase cardiac and sweat output sufficiently which may lead to increases in body temperature and potential illness or death. This includes people such as seniors, post-menopausal women, or those taking certain medications including anticholinergics, diuretics, beta-blockers, estrogen replacement drugs and some antipsychotic drugs (Lee-Chiong Jr. and Stitt, 1995; Freedman and Krell, 1999; Brooks-Asplund et al., 2000; Speizer, 2001; Gauthier et al., 2005). Infants and young children are also particularly susceptible to heat-related illnesses due to an immature thermoregulatory system (Yeo, 2004). Excessive exertion among healthy adults can also result in dehydration, heat exhaustion, kidney failure, liver damage, heat stroke or death (Hart et al., 1980; Hughson et al., 1980; Barrow and Clark, 1998; Dematte et al., 1998; Bouchama and Knochel, 2002).

Over the previous two decades, it has been estimated in the U.S. that extreme heat episodes contributed to the death of several hundred people (Confalonieri et al., 2007). Many such deaths occurred in susceptible subpopulations such as seniors with pre-existing cardiovascular, cerebrovascular or respiratory conditions. The precise number of persons with heat-related illnesses seeking medical treatment in a given year in Canada or the U.S. is unknown because no reliable statistics are available. Only a small number of deaths are certified as due to heat stroke in Canada (Koutsavlis and Kosatsky, 2003).

Over a span of several weeks, people can gradually become acclimatized to heat stress by reducing their basal metabolic rate, increasing their capacity to perspire and increasing skin blood flow (Koppe et al., 2004). Epidemiological studies have revealed an approximate U- or J-shaped relationship between temperature and mortality (Ballester et al., 1997; Keatinge et al., 2000; Koppe et al., 2004). For example, the upward slope of the "J" in Figure 4.1 begins at lower temperatures and is steeper for northerly cities in the U.S. and Europe than for cities farther south (Keatinge et al., 2000; Curriero et al., 2002). In populations with cooler climates, or during heat waves occurring early in the season, people are particularly vulnerable as they are unacclimatized to heat stress. Under such conditions, the upward slope of the mortality response curve begins at lower temperatures and is steeper (Keatinge et al., 2000; Curriero et al., 2002). Adaptive measures such as heat health warning systems, air conditioned living and work spaces, or access to cooling centres by people at risk of heat stress have been shown to reduce the extent of related health impacts (Sheridan and Kalkstein, 2004; U.K. Met Office, 2006; Vittiglio, 2006; Confalonieri et al., 2007).

Figure 4.1 Dose-response curve for mortality and temperature in 11 cities of the Eastern United States[1]



Note: -20°F, 0°F, 20°F, 40°F, 60°F and 80°F are -28°C, -18°C, -6°C, 4°C, 16°C and 26°C, respectively.

Source: Curriero et al., 2002.

4.2.2 Health Impacts of Ground-Level Ozone

Ground-level ozone is a pollutant which is formed in the atmosphere primarily from nitrogen oxides and volatile organic compounds. While there are natural sources of both these ozone "precursors", human activities produce huge quantities of both–especially those activities related to the combustion of fossil fuels. Exposure to O_3 may result in various pulmonary and cardiovascular effects in healthy individuals but is especially problematic for those with existing cardiovascular and pulmonary disease (WGAQOG, 1999a, 1999b; U.S. EPA, 2006a). Considering that some 45% of all deaths in Canada result from cardiopulmonary disease, it would appear that the potentially susceptible group is very large. The main health impacts of O_3 include acute and chronic damage to the respiratory system, with increased airway reactivity, airway permeability, airway inflammation, reduction in lung function and increased respiratory symptoms. The acute reactions are of particular concern in asthmatics, including children, and others with chronic airway disease. These effects appear to be worsened as the duration of exposure to O_3 increases (Hyde et al., 1992; Krzyzanowski et al., 1992; Künzli et al., 1997; Lippmann, 2000b). Short-term exposure to O_3 has also been associated in some studies with various cardiovascular effects including acute myocardial infarction (Ruidavets et al., 2005), arrhythmias (Dockery et al., 2005) and heart rate variability (Park et al., 2005). These results provide evidence concerning possible mechanisms behind the association detected by epidemiological studies between O_3 and premature mortality (U.S. EPA, 2006a).

4.2.3 Health Impacts of Particulate Matter

Airborne PM varies in composition and concentration and is composed of both organic and inorganic constituents. Particles are usually categorized as coarse ($PM_{10-2.5}$), fine ($PM_{2.5}$) and most recently, ultrafine ($PM_{0.1}$), with aerodynamic diameters of 10 µm (micrometres) to 2.5 µm, <2.5 µm and <0.1 µm, respectively. Although regional differences are significant,

1 The J-shaped curves depicted in Figure 4.1 were obtained using a software program to handle a statistical method known as a "generalized additive model". Following publication of the figure in Curriero et al., 2002, errors in the software came to light; re-analysis of the data in question accounting for these errors led to slightly altered but still J-shaped curves, with a slightly greater range of temperatures at which the relative risk of mortality remained flat (Curriero et al., 2003).

in general, about half of $PM_{2.5}$ is directly emitted into the atmosphere whereas the other half is secondarily formed when precursor gases (sulphur dioxide [SO_2], nitrogen oxides [NOx], VOCs and ammonia [NH_3]) react or condense to form particles (Environment Canada, 2003a). Most $PM_{10-2.5}$ is directly emitted into the atmosphere from the soil, wildfires, combustion of fossil fuels, construction activities, and road and sea salt (Environment Canada, 2003a). While $PM_{10-2.5}$ can deposit widely within the lung, it is more likely to deposit in the upper portions, while both $PM_{2.5}$ and $PM_{0.1}$ penetrate deep into the lungs and elicit a range of physiological responses and even enter into the bloodstream (Delfino et al., 2005; Penn et al., 2005; Urch et al., 2005; Lipsett et al., 2006).

Epidemiological, field, controlled human exposure and toxicology studies, which have been extensively reviewed in national risk assessments (Working Group on Air Quality Objectives and Guidelines, 1999a, 1999b; U.S. EPA, 2004) have contributed to the evidence of PM-associated health impacts. PM has been associated with hospitalizations and increased respiratory and cardiovascular mortality (Burnett et al., 1999; Burnett and Goldberg, 2003; Goldberg et al., 2006). It has also been associated with asthma exacerbation, decreased lung function, inflammation and changes in heart rate variability (McConnell et al., 1999; Gong et al., 2003c; Ebelt et al., 2005). These effects have been observed at the range of concentrations found in Canadian urban entres. Particular subpopulations, including children, seniors and people with pre-existing medical conditions are more vulnerable to the health impacts of PM. Both the short-term (from days to a few weeks) and long-term (multi-year) health impacts of exposure to PM depend on the composition of the particles (which may vary with season) and the exposed population (Goldberg et al., 2000, 2001b; Gordon, 2003; Mueller-Anneling et al., 2004; Becker et al., 2005; Crighton et al., 2005; Delfino et al., 2005; Li et al., 2005; Goldberg et al., 2006; Huang and Ghio, 2006; Kreyling et al., 2006; Ostro et al., 2006; Ren et al., 2006), though this has not been consistently found.

4.2.4 Interactions of Heat and Air Pollution

Most of the underlying mechanisms that have been investigated to explain the biological effects of heat or air pollutants on health appear to belong to distinct biological pathways. However, there is clearly an overlap in the body's physiological response to the activation of these pathways; this suggests that synergistic effects are quite plausible. For example, reduced pulmonary function due to acute O_3 exposure, or reduced heart rate variability due to PM exposure, will likely impair an individual's capacity to maintain adequate tissue oxygenation under the increased cardiovascular load associated with heat stress.

Generally, any limitation in respiratory function due to pollution could interfere with cardiovascular thermoregulatory mechanisms and reduce the maximum heat load that an individual could sustain before adverse effects appeared. As another example, both heat stress and PM can lead to blood coagulation anomalies. These could precipitate an event such as a myocardial infarction in a susceptible individual who is in a state of increased cardiovascular work due to the heat. Gordon (2003) has also suggested that the physiological stress caused by marked changes in ambient temperature can alter the physiological response to toxic agents.

Despite a theoretical basis for synergistic effects of heat and air pollution, the specific potential individual and population health impacts still need to be clarified; few studies have explicitly investigated this question. There are also other potential mechanisms by which heat could influence the effect of air pollution on health. For example, higher average temperatures are in fact associated with greater exposure to air pollution because population activity patterns change; people spend more time outside and tend to leave their windows open more often. However, it remains difficult to draw any firm conclusions based solely on this evidence. Further studies with more refined air pollution exposure measurements and assessments of other modulating factors are required.

4.2.4.1 Seasonal variations in air pollution

Differences in the health impacts of air pollution have been observed in studies examining the association between air pollution and health during different seasons. During the summer, intense sunlight and elevated temperatures often contribute to increased formation of ground-level O_3 (a component of photochemical smog), resulting in combined exposures to heat, and high levels of O_3 as well as PM. Differences in the response to PM_{10}—which does not follow predictable variations throughout the year—are more suggestive of an interaction with heat, provided that the effect of O_3 has been controlled for. O_3 levels are positively correlated with PM_{10} levels during the summer months (Ito et al., 2005) and negatively correlated during the winter months. As with PM_{10}, the observed season- and temperature-dependent effects of nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon monoxide (CO) on mortality, physician consultations and hospital admissions (Michelozzi et al., 1998; Hajat et al., 1999; Chang et al., 2005), suggest the existence of underlying interactions.

Using a case crossover design to look at hospital admissions for cardiovascular diseases in Taipei between 1997 and 2001, Chang et al. (2005) performed separate analyses within two temperature strata: cool days (mean temperature <20°C) and warm days (>20°C). They found that NO_2, CO and O_3 were significantly associated with increases in hospitalizations on warm days (after adjusting within the two strata for the effects of potential confounding factors such as temperature, humidity and other pollutants). On cool days, only PM_{10} had a statistically significant effect after adjusting for the effects of other air pollutants.

Goldberg et al. (2001d) found positive correlations between O_3 and non-accidental deaths in Montreal during the summer, whereas during the winter, the correlations were negative. In a recent review of 10 time-series studies examining the association between O_3 and mortality (Ito et al., 2005), nine studies found higher estimates of mortality risk with increasing O_3 levels during the warm months when O_3 levels were higher (winter risk due to O_3 exposure was only higher in one city in Australia). Adjusting for the effects of PM_{10} did not markedly affect the results.

In a meta-analysis of studies examining the short-term effects of air pollution in eight Italian cities, Biggeri et al. (2005) found a significant difference in the effect of PM_{10} on all-cause mortality by season, with a 0.54% increase in mortality observed in the cold season and a 2.53% increase observed in the warm season (both increases are for a 10 µg/L increase in PM_{10} concentration). The variability of the size of the effect among cities was also greater during the warm season. O_3 and other pollutants were not considered here.

In a time-series analysis of the effects of major air pollutants, Michelozzi et al. (1998) found that total mortality in Rome from 1992 to 1995 was positively associated with PM_{10} (as well as NO_2), with a 0.4% increase in mortality observed with each increase of 10 $\mu g/m^3$ PM, increasing to 1.0% in the summer months. Sunyer et al. (1996) conducted a similar study in Barcelona and found that daily variations in mortality were related to daily variations in air pollutants for the period 1985 to 1991. Adjusted for temperature and other factors, black

smoke (black particles with a diameter of less than 4.5 µm) and SO_2 were positively related to total mortality, seniors' mortality, and cardiovascular mortality. The association between SO_2 and respiratory mortality in seniors, however, was significant only during the summer months. NO_2 and O_3 were positively related with mortality in seniors and cardiovascular mortality during the summer, but again not during the winter months.

In a study that examined physician consultations for asthma in London (Hajat et al., 1999), the effect of various air pollutants was compared between seasons for different age groups. Statistically significant seasonal differences were observed for NO_2 in children, and for black smoke and PM_{10} in seniors, with larger effects observed during the summer months. Among adults, increasing O_3 levels during the summer were associated with an increase in medical consultations.

Anderson et al. (1996) found a year-round increase in respiratory mortality due to O_3 in London (U.K.), whereas all-cause and cardiovascular mortality were affected only during the warm season. This suggests that persons suffering from cardiovascular diseases may be more susceptible to a combination of O_3 and heat compared with those suffering from respiratory diseases, who appear to be equally susceptible to O_3 year-round. Black smoke was also positively associated with all-cause mortality during both seasons, but more so during the summer months. The results were similar when adjusting for the effects of PM_{10}.

4.2.4.2 Cross-city comparisons

Studies examining the effects of air pollution on health between warmer and cooler cities have also tended to suggest greater impacts on health in warmer climates. However, the results of such studies must be viewed cautiously because of the existence of potential confounding effects of other factors.

Barnett et al. (2005) examined the relationship between air pollution and child hospital admissions for respiratory diseases in five cities in Australia and New Zealand. They found that increases in respiratory disease admissions associated with $PM_{2.5}$ and PM_{10} in the 1- to 4-year-old age group occurred mostly during the warm season, whereas an association with NO_2 in the older children (aged 5 to 14 years), although greater during the warm season, was present during both warm and cool seasons. Cities with higher average temperatures were also found to have greater increases in hospital respiratory disease admissions in the 1- to 4-year-old age group associated with 1-hour NO_2 concentrations.

Diaz et al. (2004) investigated the combined effects of heat and air pollution on child mortality in Madrid, Spain, between 1986 and 1997. High temperature alone was not found to be associated with higher mortality. However, air pollutants such as total suspended particles and NOx had a strong seasonal effect on mortality. During the summer months, the relative risk of daily mortality from elevated total suspended particles was 1.53 in infants aged 1 to 5 years compared with 1.25 during the winter months. NOx had a significant effect only in the summer months in the 0- to 1-year-old age group, with a relative risk of 1.07 reported.

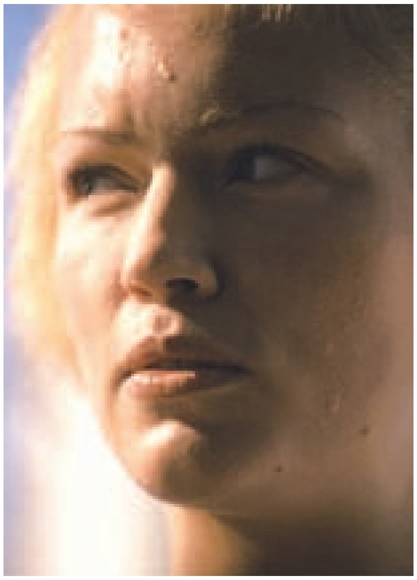
Aga et al. (2003) also found that temperature partly explained differences observed in air pollution-related mortality among seniors in 28 cities examined in the *Air Pollution and Health: A European Approach 2* (APHEA2) study. In cooler cities with a 9°C daily average temperature (25th percentile), a 10 µg/m^3 increase in PM_{10} caused an increase in mortality in seniors of only 0.44%. In contrast, a 0.91% increase was found in warmer cities with a 15°C daily average temperature (75th percentile). For black smoke, the mortality increase varied from 0.39% to 0.75% among cooler and warmer cities, respectively.

As part of the APHEA2 study, Katsouyanni et al. (2001) examined the short-term levels of air pollutants, ratios of PM_{10} to NO_2 and black smoke, mean temperature and humidity, as well as population characteristics in relation to overall mortality in several cities. The daily mortality increase for PM_{10} was 0.29% at the 25th percentile of average temperature, which increased to 0.82% at the 75th percentile of average temperature. The effects of black smoke depended partly on temperature. The mortality increase varied from 0.23% to 0.70% among cities at the 25th percentile of average temperature compared with those at the 75th percentile. This study may have been flawed, however, because of the use of inappropriate regression methods.

Choi et al. (1997), in one of few long-term studies examining the influence of temperature on the effects of air pollution, assessed lung cancer mortality in 47 Japanese prefectures as a function of long-term NO_2 and SO_2 levels, expenditures on tobacco, car density, temperature and geographic gradient (north to south). For the southern and warmest areas, the NO_2 effect was strongest where average temperatures were highest, possibly suggesting an additive or synergistic effect of long-term exposure to air pollution and higher temperature on risk of lung cancer mortality.

4.2.4.3 Studies of extreme heat events and their effects on air pollution-related population health risk

Heat waves provide opportunities to study the influence of temperature on the health impacts of air pollution. This is because they often combine high and/or sustained levels of both heat and air pollutants and the impacts of their interactions become more evident. Some studies have tended to suggest that interactions between heat and air pollution do occur but only become measurable above a certain temperature threshold (Sartor et al., 1997).



In a study of the effects of the 2003 heat wave in France, a daily time-series analysis for nine cities was performed (Institut de veille sanitaire (InVS), 2004). Daily O_3 concentrations, and minimum and maximum temperatures were inputted for the 8-year period from 1996 to 2003. Daily deaths were regressed on same-day and earlier temperatures and on O_3 concentrations the day of and the day before the deaths occurred. The effect of O_3 alone, temperature alone, and O_3 acting with temperature were estimated for August 3 to 17, the period of the heat wave. It was found that O_3 and temperature effects differed among some of the nine cities. Although overall the temperature effect was preponderant, O_3 itself accounted for most of the deaths in two cities, and no interaction was observed between O_3 and temperature.

Fischer et al. (2004) in Holland and Stedman (2004) in the U.K. used a risk assessment approach to estimate air pollution-related deaths during the August 2003 heat wave. Deaths were estimated on the basis of country-specific dose–response relationships for O_3 and $PM_{2.5}$ and were subtracted from the overall number of excess deaths during the heat wave. For the U.K., Stedman (2004) estimated that 21% to 38% of the total excess deaths were associated with elevated concentrations of O_3 and/or particles. Fischer et al. (2004) estimated that in the Netherlands, approximately 40% of the 1,000 to 1,400 excess deaths were related to air pollution.

Sartor et al. (1995) studied the association among daily deaths, temperature and air pollutant concentrations during a prolonged period of above normal temperatures in Belgium in 1994. Expected mortality was based on the summers of 1985 to 1993. In 1994, a net excess of 1,226 deaths occurred during a period of hot weather with above average O_3 levels. For persons more than 65 years of age, the statistical interaction between the logarithm of O_3 and temperature, both measured the day before, contributed to 40% of the logarithm of daily deaths. Additional analyses for this age group were based on tertiles of mean daily temperature (Sartor et al., 1997). At the lowest temperatures, temperature and O_3 were not correlated, and only O_3 was associated with mortality. In the middle tertile, temperature and O_3 were highly correlated, and daily deaths also varied with the concentration of O_3. In the tertile where mean temperature was highest (21–27°C), temperature was the stronger predictor of daily deaths, with a positive interaction between temperature and O_3 observed.

Katsouyanni et al. (1993) studied excess mortality across several urban areas in Greece during a heat wave in July 1987. Athens (a "high-pollution" city) was compared with a group of 14 other smaller ("low-pollution") cities. The excess of mortality in Athens was statistically different than that in the other cities after controlling for temperature, suggesting that air pollution had an effect on mortality independent from air temperature. This result is similar to the cross-city effects observed in the APHEA studies, although their designs and methodologies are different. Study limitations include the fact that mean air temperature was averaged over the entire 1-month period and there was a lack of real data for pollutants and other confounders.

4.2.4.4 Synoptic air mass studies

Studies of synoptic air masses examining the effects of air pollutants on population health outcomes (Pope and Kalkstein, 1996; Samet et al., 1998; Smoyer et al., 2000) did not produce any evidence that temperature influenced the effects of air pollutants. The synoptic air mass approach (Kalkstein, 1991) has been used to study the impact of multiple meteorological variables on health. Synopses are meteorological descriptors that take into account a number of weather parameters (e.g. temperature, humidity, cloud cover, wind direction and speed), describing these grouped variables as air masses, which are generally named according to their geographic origin. They can also be classified according to a similarity to a classic weather pattern, or by automatic classification methods that cluster coincident weather variables into groups having preset characteristics.

Using synoptic classification of air masses in four major Canadian cities (Montreal, Ottawa, Toronto and Windsor), Cheng et al. (2005) quantified an increase in heat-related mortality by the 2050s and 2080s as a result of climate change. Although the influence of temperature on air pollution effects was not examined specifically, an increase in air pollution-related mortality, largely driven by O_3, was observed for one of the scenarios where emissions were not modified.

4.2.4.5 Laboratory and field studies

Laboratory and field studies, although limited, have provided some evidence of interactions between air pollutants and temperature. Some data from laboratory studies suggest that high ambient temperatures increase the toxicity of CO (Yang et al., 1988). The temporal association between peak expiratory flow rates and ambient O_3 was studied in a group of 287 children and 523 non-smoking adults in Tucson, Arizona (Krzyzanowski et al., 1992). In children, peak expiratory flow rates were reduced on days when there was a higher O_3 concentration. In adults, peak expiratory flow rates were reduced in asthmatics who spent more time outdoors on days when O_3 levels were higher. After adjusting for other co-variates, significant interactions among O_3, PM_{10} and temperature were found; the impairment of the respiratory response due to low-level ambient O_3 increased with temperature and PM_{10}.

Chapter 4

4.2.5 Vulnerable Populations

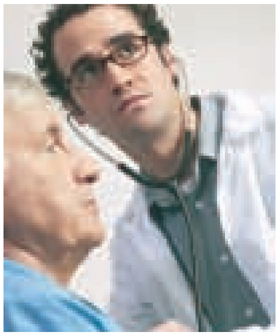
As noted earlier, it is clear that many factors can affect an individual's health risks resulting from exposure to environmental stresses such as ambient air pollution and/or heat.

Population groups most vulnerable to the effects of natural and anthropogenic air pollution emissions and/or extreme heat are relatively well identified (Neas et al., 1996; Lippman, 2000a; Ledrans and Isnard, 2003; Jerrett et al., 2004; Newhouse and Levetin, 2004; Carcaillon et al., 2006):

- seniors and those in institutions, such as residential care homes;
- young children and asthmatics;
- people with chronic diseases, particularly cardiovascular and respiratory illnesses, renal disease, diabetes and obesity, as well as those taking certain medications; and
- people of lower socio-economic status and those living in densely populated urban neighbourhoods.

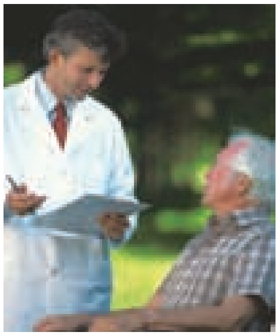
The latter group is at greater risk of the adverse health impacts of air pollution mainly because of living conditions that lead to higher exposures to ambient PM, gaseous pollutants and traffic emissions. In addition, people of low socio-economic status have a greater incidence of illness (Finkelstein et al., 2005).

Under conditions of combined heat and pollution, vulnerable groups may experience greater risks than the general population. However, it is difficult to evaluate who might exhibit more sensitivity to potential synergistic effects; such questions have not yet been formally addressed in the literature. Evidence pointing to specific groups that might be particularly sensitive is very limited.



4.2.5.1 Persons with cardiovascular disease

As already noted, Anderson et al. (1996) found that the association between O_3 and related respiratory mortality in London (U.K.) was significant throughout the year, whereas association with cardiovascular mortality was significant only during the warm season. Similar findings were reached by Sunyer et al. (1996). This could suggest that synergistic effects are more prevalent in people with cardiovascular diseases. In addition, such people appear to be affected by air pollution only when temperatures are warmer.



4.2.5.2 Seniors

Roberts (2004) observed interactions between air pollutants and ambient temperatures while studying mortality in people aged >65 years, and Aga et al. (2003) found suggestive evidence for this in a study of this age group. In another APHEA study of all-age mortality (Katsouyanni et al., 2001), the effect modification by temperature on air pollution-related mortality was comparable to that found by Aga et al. (2003) in seniors. Mortality due to air pollution in an urban study was slightly higher in seniors than in the general population; there was also a slightly higher effect on mortality for the general population in warmer cities. However, the effect modification by temperature of air pollution-related mortality was approximately the same in seniors and the general population. This study therefore suggests that although the adverse health impacts of air pollution are greater in seniors, the impacts of combined exposure to pollution and variations in temperature may be similar in seniors and in the general population. Most of the victims of heat waves in Europe and North America have been seniors whose health is already fragile (Bouchama and Knochel, 2002; Curriero et al., 2002; Diaz et al., 2002; Hémon and Jougla, 2003; Ledrans and Isnard, 2003; Fischer et al., 2004; Kovats et al., 2004; Toulemon and Barbieri, 2004). Future research should investigate the possible synergistic role of poor air quality in contributing to morbidity and mortality during heat waves.

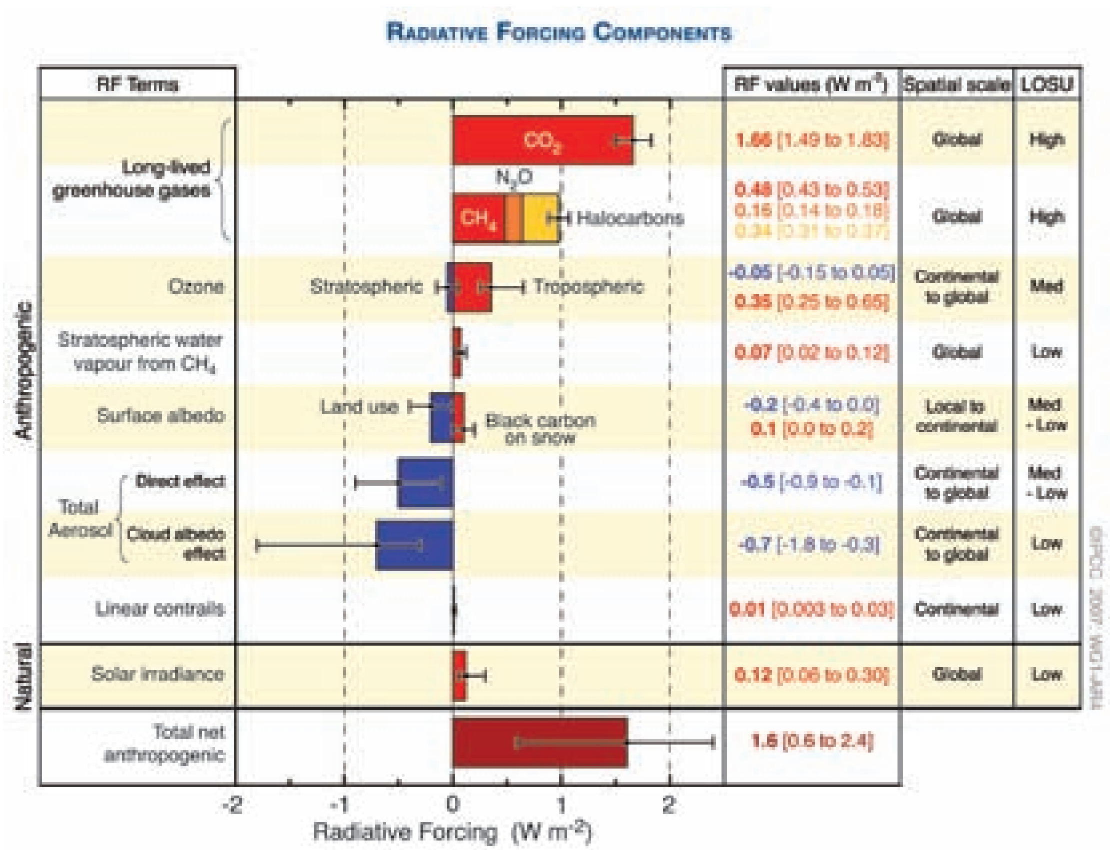
4.2.5.3 Children

Hajat et al. (1999) observed seasonal variations in the effect of pollution on medical consultations for asthma in children as well as in seniors. Similarly, Barnett et al. (2005) found that in children aged 1 to 15 years, the association between air pollution and hospital admissions was greater during the warm season. Diaz et al. (2004) also found that air pollutants had a greater impact on child mortality during the warm season.

4.3 CLIMATE CHANGE AND AIR POLLUTION

Carbon dioxide (CO_2) and other carbon-based GHGs contribute to climate change, whereas airborne PM (other than black carbon) can have a cooling effect by reflecting incoming solar radiation back into space (IPCC, 2007a). Figure 4.2 illustrates some of the major physical and chemical factors that influence the warming and cooling of the Earth's atmosphere (IPCC, 2007a).

Figure 4.2 Major factors influencing atmospheric warming and cooling



Global average radiative forcing (RF) (watts per square metre) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown.

Source: IPCC, 2007a. *Climate Change 2007: The Physical Science Basis, Summary for Policymakers* (Figure SPM.2, page 4)

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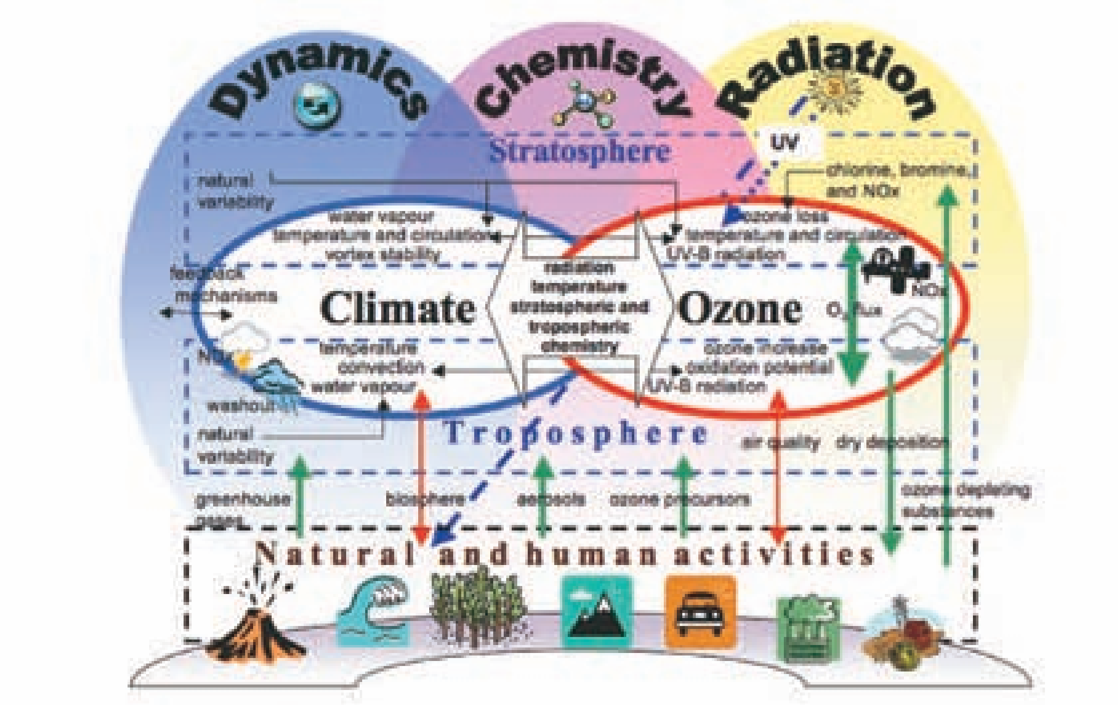
The atmosphere and the earth's surface receive heat energy from the sun in the form of visible and invisible radiation. Global atmospheric warming occurs because incoming solar radiation energy is retained; this is mediated in part by GHGs and other atmospheric components such as halocarbons, nitrous oxide (N_2O), methane (CH_4), CO_2, tropospheric O_3, dusts, and black carbon from fossil fuel and biomass burning. Warming is counterbalanced by the cooling effects of stratospheric O_3, sulphate aerosols, organic carbon from fossil fuel and biomass burning, and by an increased reflectivity of the land surface due to deforestation in snow-covered forests (IPCC, 2007a). Under the present atmospheric conditions, with rising levels of CO_2 and other GHGs, the overall warming effect is of greater magnitude than the overall cooling effect. The reduction of secondary aerosol precursors, NOx, NH_3, SO_2 and VOCs, through efforts to improve air quality, is expected to lead to an increase in temperature. The cooling effect of sulphate aerosols may have partially masked the extent of global warming (U.K. DEFRA, 2005).

4.3.1 Effect of Climate Change on Particulate Matter and Ozone

Climate change could alter air quality by modifying the complex mechanisms affecting the formation and behaviour of PM and O_3. As outlined by Bernard et al. (2001), Lloyd (2001), IPCC (2007b) and others, climate change could influence levels of ambient pollutants by modifying (1) weather and consequently local and regional air pollution levels; (2) anthropogenic emissions; and (3) natural emissions, which are strongly controlled by temperature.

Figure 4.3 illustrates the complexity of the atmosphere, and the physical and chemical interactions that affect the behaviour and concentration of air pollutants. Changes in the height of atmospheric layers that determine the vertical distribution of pollutants can alter their concentration (U.S. EPA, 1989; Hogrefe et al., 2004; Laurila et al., 2004b). Global warming may also accelerate the transfer of O_3 from the stratosphere to the troposphere where it would add to the formation of smog (Collins et al., 2003).

Figure 4.3 Interactions among climate, atmospheric composition, chemical and physical processes driven by solar radiation energy and natural and human activities



Source: Adapted from Integrated Global Observing Strategy (IGOS), 2004.

Mickley et al. (2004) conducted an analysis of the effect of projected future climate conditions (1950–2052) on pollutant levels in the U.S. Their general circulation model simulations included black carbon and carbon monoxide (CO) as tracers, and indicated that the concentration of both pollutants increased by 5 to 10% during pollution episodes, although actual emission levels for both tracers were kept constant over the simulation period. This suggests that the magnitude and duration of air pollution episodes could increase as a result of a warmer climate. Changes in the frequency and magnitude of simulated air pollution episodes were also associated with reduced cyclonic weather patterns, which are usually indicative of air pollution. Increases in anticyclonic conditions would cause more frequent inversions that would result in severe air pollution episodes (Hulme and Jenkins, 1998).

Leung and Gustafson Jr. (2005) modelled regional climate change scenarios (based on the IPCC A1B scenario for the years 2045 to 2055) to estimate the potential effects of climate change on U.S. air quality compared to the 1995–2005 period. They found that during autumn in the western U.S., increases in air temperature of up to 4°C increased solar radiation, reduced rainfall frequency, increased air stagnation associated with large high-pressure systems and resulted in deteriorated air quality.

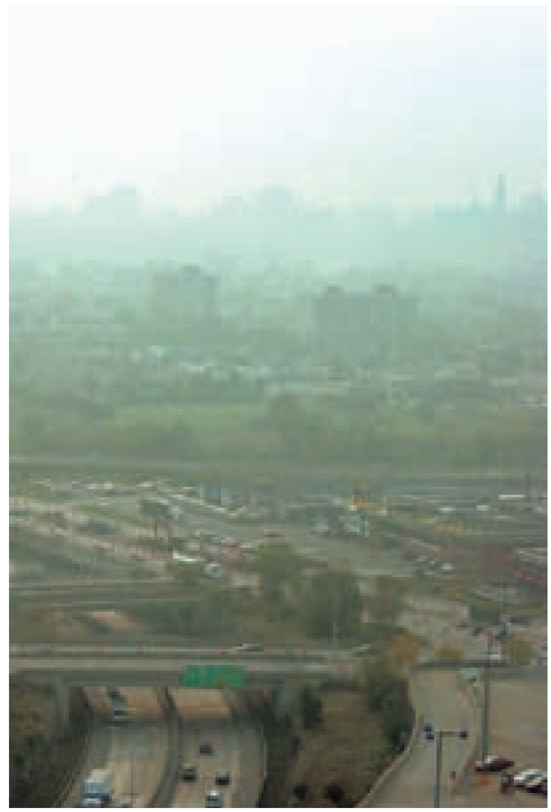


Photo Credits: Environzone, Environnement Canada (http://www.eg.gc.ca/envirozine)

Ottawa under smog

Prather et al. (2003) summarized results from 14 independent three-dimensional global tropospheric chemistry models. Using six varying global emissions estimates, they arrived at global average increases in tropospheric O_3 for the year 2030 of between 5 ppb and more than 20 ppb, in the case of two of the more extreme emissions scenarios. Using different assumptions, Anderson et al. (2001), Tuovinen et al. (2001), Knowlton et al. (2004), Laurila et al. (2004a) and Langner et al. (2005) found similar results.

Hogrefe et al. (2004) conducted an extensive assessment of the implications of climate change for O_3 formation in the U.S. for the 1990s, 2020s, 2050s and 2080s. A global climate model using the IPCC Special Report on Emission Scenarios A2 scenario (one of the most pessimistic scenarios) was coupled with a regional model to obtain current and future regional climate fields. Projections of future biogenic emissions and anthropogenic emissions remained the same. Results for five consecutive summers during the 2020s, 2050s and 2080s suggested that daily maximum 8-hour O_3 levels would be increased by 2.7 ppb, 4.2 ppb and 5.0 ppb, respectively, in the central and eastern parts of the U.S.. Larger increases were projected in certain urban corridors, whereas some decreases were observed in other specific locations. An increase in the number of days with exceedances of the current U.S. 8-hour O_3 standard and an increase in the length of the O_3 episodes were also observed.

4.4 AIR QUALITY MODELLING IN CANADA

A study was undertaken for the Assessment to investigate how a global climate 4°C warmer might affect air quality in Canada. Using A Unified Regional Air-quality Modelling System (AURAMS), a model developed at the Meteorological Service of Canada, levels of O_3 and PM were projected. This section describes the study methodology used and the modelling results.

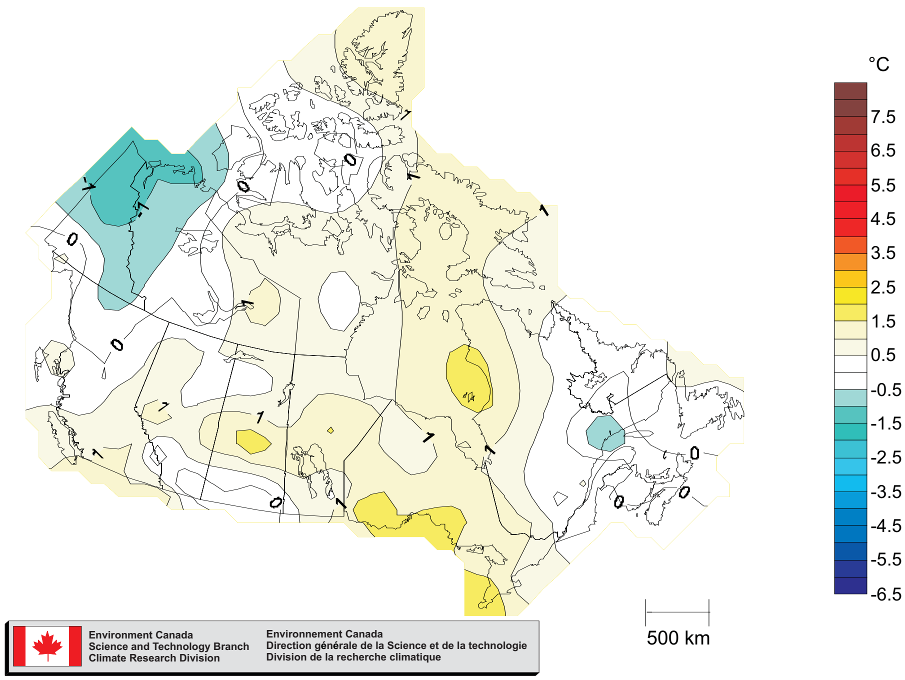
4.4.1 AURAMS: Scenarios and Assumptions

Two scenarios of increasing complexity were used to isolate (1) the individual effects of an increase in temperature on air quality (scenario CC4) and (2) the effects of changes in biogenic emissions of air pollutant precursors along with increases in temperature (scenario CC4b). Because air pollutant levels and temperatures tend to be highest during the summer months, the air pollutant concentrations were modelled for June, July and August. A detailed description of the model and its components is given in Annex 2.

A single temperature increase was used to represent projected climate warming. The Third IPCC Assessment Report (2001b) stated that globally averaged surface temperatures are expected to increase by 1.4 to 5.8°C over the period 1990–2100, based on a range of climate model simulations. Although this may not be representative of specific climate changes at the regional level, it provides a reasonable temperature bracket within which to work. For comparability with previous studies, a 4°C increase in average surface temperature was selected for the current study. This temperature increase is identical to that used by Morris et al. (1995) but is somewhat more conservative than the 5.8°C simulated by Hogrefe et al. (2004). The Fourth IPCC Assessment Report projects that the global average temperature in the decade from 2090–2099 is “likely” to be 1.1 to 6.4°C higher than that of the 1980–1999 period, depending on the emissions outlook used (IPCC, 2007a). The modelled temperature increase in the current exercise therefore represents one plausible future scenario within this range.

The year 2002 was used as a reference year for the simulations. Although no single summer can truly represent average climate conditions, the only alternative to performing simulations with multiple years is to choose a base year that is as representative as possible of the average. Figure 4.4 illustrates how the meteorological conditions experienced during summer 2002 compared with the 30-year normal, based on the Climate Trends and Variations Bulletin for 2002 (Environment Canada, 2002a).

Figure 4.4 Year 2002 regional summer time deviations in temperature from "average"



Temperatures across most of Canada were 0.5°C above normal for the summer (June, July and August) of 2002, and as a whole, Canada experienced its 19th warmest summer above normal since nationwide records began in 1948. Figure 4.4 does illustrate, however, that the warmth was neither extreme nor uniform throughout the country. From southern British Columbia through to the western edge of Quebec, and up into Nunavut, temperatures ranged anywhere from 0.5°C to 1.5°C above normal. Yukon, northwestern Northwest Territories and a small area around the mouth of the St. Lawrence River were the only areas that experienced a cooler than normal summer.

The analysis focussed on contaminant measurements that reflect current risk management goals in Canada: namely, the 8-hour daily O_3 maximum and the 24-hour $PM_{2.5}$ mean concentration, which are the metrics used for the Canada-wide Standards (CWS) for these pollutants. For the purpose of the present analysis, only the numerical targets were used, and an exceedance is assumed once the average 8-hour concentration of O_3 or the 24-hour average of $PM_{2.5}$ exceeds the CWS of 65 ppb and 30 $\mu g/m^3$, respectively, throughout the course of a day. For simplicity, the CWS levels are used as reference values throughout the analysis, although they do differ from the values of the American National Air Quality Standards. As described later (section 4.6.1), the CWS are based on feasibility of attainment and thus population health impacts may occur even when pollutant levels are within the CWS. Resultant impacts on health are presented later in the report (Section 4.5) based on all population exposures, regardless of the attainment status of the CWS for PM and ozone.

Compared with actual measurements, model simulations may present some discrepancies that can be attributed to various factors. Model results are nonetheless valuable for estimating the directions in which the future atmospheric composition may evolve. It is generally recognized that the differences between two simulations present less uncertainty than those in the reference simulation when compared to actual observations. Therefore, the present analysis will emphasize differences among the two modelling scenarios and the base case.

It is important to understand that the scenarios used in the current study were not developed with the objective of predicting how climate change would precisely impact air quality. Rather, the current study evaluated only two of the potential factors associated with climate change, namely increases in temperature and higher biogenic emissions (VOCs from plants and nitric

oxide [NO] from soil). As mentioned previously, climate change would also interfere with present climatic conditions and likely modify anthropogenic emissions. All of these factors could in turn affect ambient levels of O_3 and $PM_{2.5}$. Therefore, no definitive conclusions, only indications, can be drawn from the results of the current study regarding the effects of a future warmer climate on the levels of O_3 or PM in the air.

4.4.2 Modelling Results

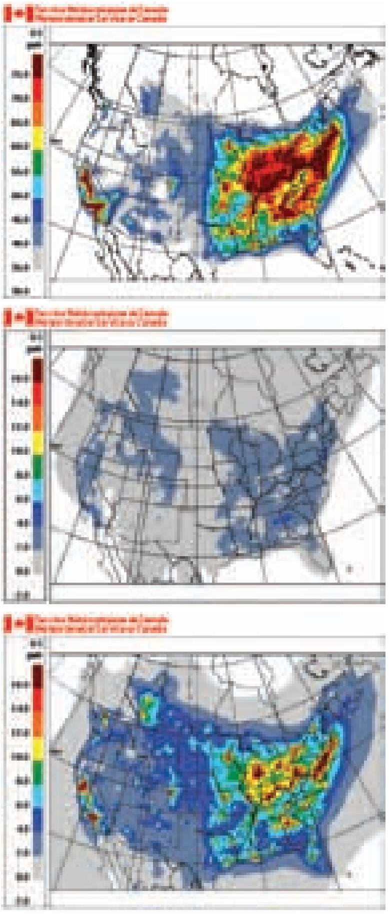
The following section presents the results of the scenario simulations for O_3 and $PM_{2.5}$. Overall, results for O_3 support the hypothesis that in a 4°C warmer climate, increased emissions of biogenic VOCs and soil NO may result in higher ambient O_3 concentrations. In contrast, reductions in the average $PM_{2.5}$ concentration were observed from baseline. Such reductions in $PM_{2.5}$ may be explained by changes in the sulphate–nitrate–ammonium–water system that controls a large fraction of the PM mass. However, given the relative uncertainty attached to PM atmospheric processes and modelling, further research is needed to better elucidate the effect of climate change on PM formation.

4.4.2.1 Ozone

Changes in average daily 8-hour maximum

Figure 4.5 presents the average daily 8-hour O_3 maximum over the three summer months for the base case (BC) simulation (top panel); the relative change in the CC4 simulation, representing a temperature increase of 4°C, compared with the BC simulation (middle panel); and the relative change in the CC4b simulation, representing the same 4°C temperature increase and taking into account a change in biogenic emissions of air pollutant precursors, compared with the BC simulation (bottom panel).

Figure 4.5 Summer time average daily 8-hour O_3 maximum (ppb)



Note: Top panel: Base case simulation. Middle panel: Relative change in the CC4 simulation compared with the base case simulation. Bottom panel: Relative change in the CC4b simulation compared with the base case simulation.

In the BC simulation, the average summer time daily 8-hour O_3 maximum value was 33.5 ppb, with values ranging from 5.4 ppb to 142.3 ppb. The highest concentrations (above 75 ppb) were simulated in the most densely populated areas of North America. In Canada, the highest average daily 8-hour O_3 maximum values are projected for southern Ontario, Quebec and in the Vancouver area, where they reach values of approximately 60 to 70 ppb.

In the CC4 simulation, an overall increase in the average daily 8-hour O_3 maximum values was observed, induced by the increase in air temperature. The average daily 8-hour O_3 maximum value was 34.5 ppb, an overall 0.9 ppb increase from the BC simulation. As in previous studies (Morris et al., 1995; Aw and Kleeman, 2003; Hogrefe et al., 2004), an increase in temperature accelerated chemical reaction rates and therefore increased the rate at which O_3 and other oxidants were produced. The increase in O_3 in the CC4 simulation was not higher than 6.0 ppb in any of the modelled locations.

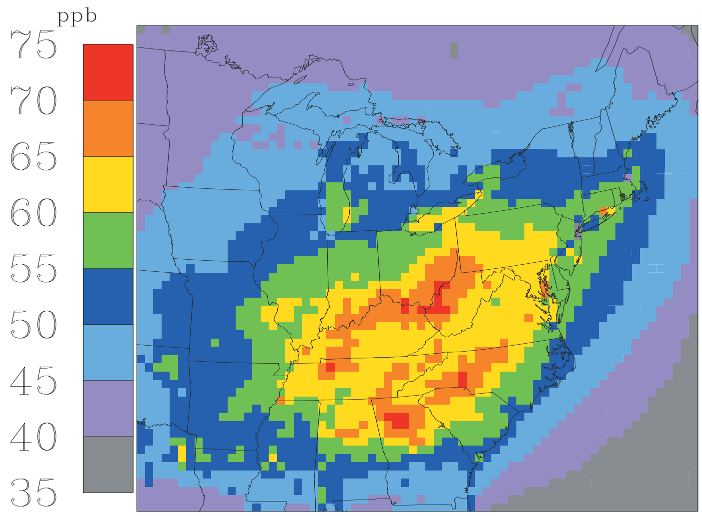
In the CC4b simulation, where biogenic emissions are also stimulated due to increased temperature, the overall average daily 8-hour O_3 maximum was 36.9 ppb, a 3.4 ppb increase from the BC simulation. The increase in the average daily 8-hour O_3 maximum also exceeded 10 ppb in places. The highest Canadian increases in O_3 concentrations (10 to 18 ppb) from the BC simulation were projected for Montreal, Toronto, Vancouver, Calgary, Edmonton, and Winnipeg. A large increase of up to 18 ppb can also be noted in Alberta, mainly in the vicinity of oil sands developments near Fort McMurray. The increased soil NO emissions over the Prairie regions (e.g. in Alberta, Saskatchewan and midwestern U.S.) also contribute to the increase in O_3 concentrations modelled for those areas.

In the CC4b simulation, biogenic emissions of VOC species, such as isoprene and monoterpenes, increased by 25 to 50%, and in some areas by as much as 100%, as a result of the 4°C increase in temperature. The biogenic monoterpene emissions increased most prominently over the northwestern and southeastern U.S., with the exception of the Illinois and Ohio area. Isoprene emissions increased over the boreal forest regions of Canada. The large increases in O_3 concentrations observed in the Illinois and Ohio regions and extending to large cities in the adjoining states are attributable to the increase in biogenic emissions of VOCs in the surrounding regions and to locally increased emissions of NO from soil (up by 15%).

In a similar study, Hogrefe et al. (2004) obtained future year climate conditions by coupling the MM5 and GISS models.[2] Results for the 2080s, where the temperature increased by 4.3°C for the GISS and by 5.8°C for the MM5, are comparable to those obtained from the CC4b scenario here. Figure 4.6 depicts the spatial distribution of the average summer time daily 8-hour O_3 maximum projected by Hogrefe et al. (2004) for the 1990s. Figure 4.7 represents the change in the 2080s scenario from 1990. Despite many differences between the current study and that of Hogrefe et al. (2004), the magnitude of the projected change in both the CC4b simulation here and the corresponding scenario from Hogrefe et al. (2004) is similar.

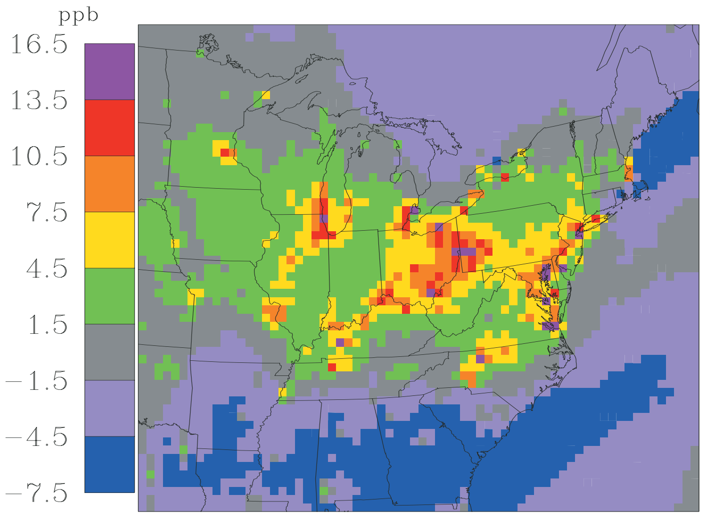
2 MM5 is the Pennsylvania State University/National Centre for Atmospheric Research mesoscale regional climate model. More information about this model is available in Grell et al. (1994). GISS AOM is the Goddard Institute for Space Studies coupled Atmosphere-Ocean Model. More information about this model is available in Russell et al. (1995).

Figure 4.6 Summer time projected average daily maximum 8-hour O_3 maximum concentration (ppb) for the 1990s



Source: Hogrefe et al., 2004.

Figure 4.7 Changes in summer time average daily maximum 8-hour O_3 concentration (ppb) projected under the 2080s climate change scenario simulation relative to that for the 1990s

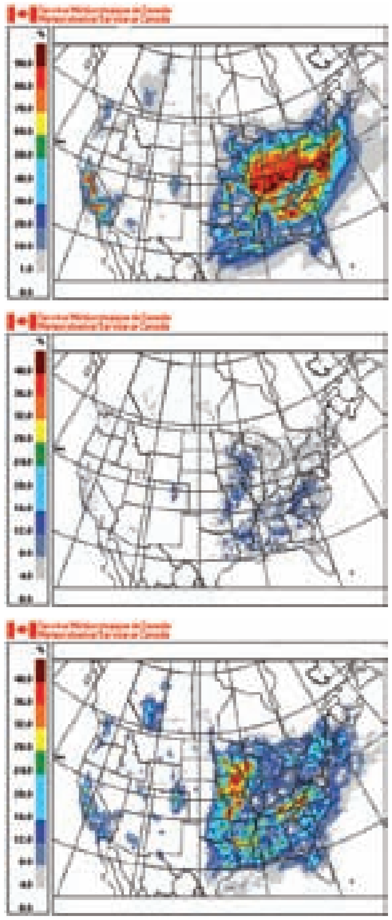


Source: Hogrefe et al., 2004.

Changes in the frequency of exceedances

The top panel of Figure 4.8 presents the number of exceedances of the CWS for O_3 in summer in the BC simulation. Multiple exceedances during the day are counted only as a single exceedance. In Canada, the highest number of exceedances ranges from about 40 to 80% along the Quebec–Windsor corridor. Areas near Vancouver and in Alberta also present a significant number of exceedances of the CWS for O_3.

Figure 4.8 Percentage of days with average 8-hour O_3 concentration exceeding the Canada-wide Standard of 65 ppb



Note: Top panel: Base case simulation. Middle panel: Difference in number of exceedances between the CC4 simulation and the base case simulation. Bottom panel: Difference in number of exceedances between CC4b simulation and the base case simulation.

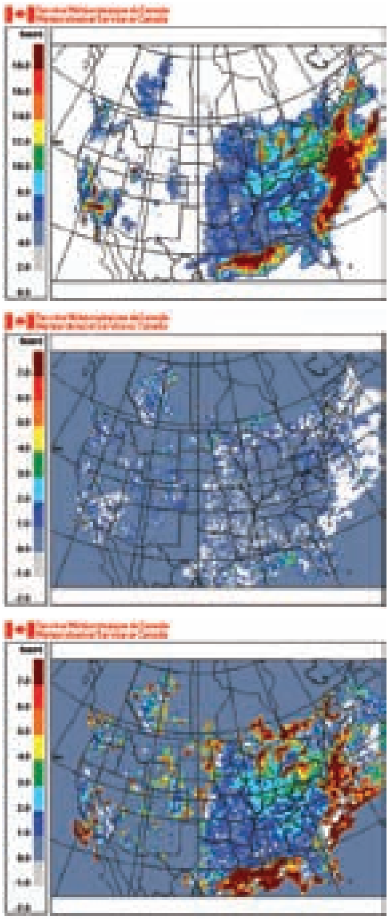
The middle panel of Figure 4.8 presents the relative increase in the number of summer time O_3 exceedances between the CC4 and the BC simulations. The average number of exceedances rose slightly from 10.0% in the BC simulation to 11.2%. In Canada, changes in the number of exceedances are less intense, and are generally below 10%. Changes at the local level varied from -5.4 to 22.8%.

The bottom panel of Figure 4.8 presents the relative increase in the number of summer time O_3 exceedances between the CC4b and the BC simulations. The CC4b scenario projected greater changes in the number of exceedances than the CC4 simulation, with some regions of the U.S. exhibiting an increase of more than 40%. Overall, the average number of exceedances in the CC4b simulation was 14.8%, with local variations ranging from 0 to 51.1%. In Canada, the largest increases are again observed in the Quebec–Windsor corridor, and range from 10 to 25% in Alberta and Vancouver.

Changes in the duration of exceedances

The top panel of Figure 4.9 presents the simulated average duration (in hours) of summer time O_3 exceedances in the BC simulation. The average duration of exceedances varied between 0 and 52 hours, but tended to be shorter above the continental landmass, where episodes generally lasted between 0 and 20 hours.

Figure 4.9 Duration (hours) of summer time episodes with O_3 concentration greater than 65 ppb



Note: Top panel: Base case simulation. Middle panel: Difference in average duration of exceedance between the CC4 simulation and the base case simulation. Bottom panel: Difference in average duration of exceedance between CC4b simulation and the base case simulation.

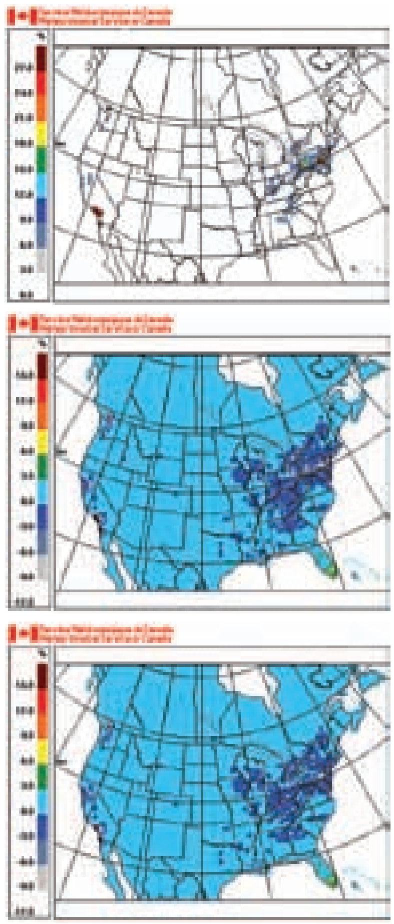
To highlight changes in the persistence of extreme O_3 events, the middle panel of Figure 4.9 presents the changes in CC4 simulation relative to the BC simulation. Changes above the continental landmass generally ranged from -4 to +7 hours with an average change of 0.1 hour.

The bottom panel of Figure 4.9 presents the changes in the CC4b simulation relative to the BC simulation, and indicates that several parts of Canada would experience average durations of summer time O_3 exceedance of more than 7 hours. The duration of O_3 episodes in some locations in Canada, however, would decrease slightly. The average length of O_3 exceedance increased by 1.5 hours from the BC simulation. In the CC4 and CC4b simulations, the average duration of O_3 exceedances would increase by up to 30 hours in some regions.

4.4.2.2 Fine particulate matter

Figure 4.10 presents the percentage of days with average 24-hour $PM_{2.5}$ concentrations exceeding the CWS of 30 µg/m^3 for the BC, CC4 and CC4b simulations. Simulated summer time $PM_{2.5}$ concentrations seem to be less influenced than O_3 concentrations by the imposed temperature increase. In the BC simulation, the number of days with an exceedance was 4.5% overall, though in some regions including Los Angeles, Vancouver, New Orleans, Toronto and the Ohio River Valley the increase was over 20%. Although not presented graphically, mean daily maximum 24-hour $PM_{2.5}$ concentrations were 8.9 µg/m^3 in the BC simulation.

Figure 4.10 Percentage of days with an average 24-hour $PM_{2.5}$ concentration exceeding the Canada-wide Standard of 30 µg/m³



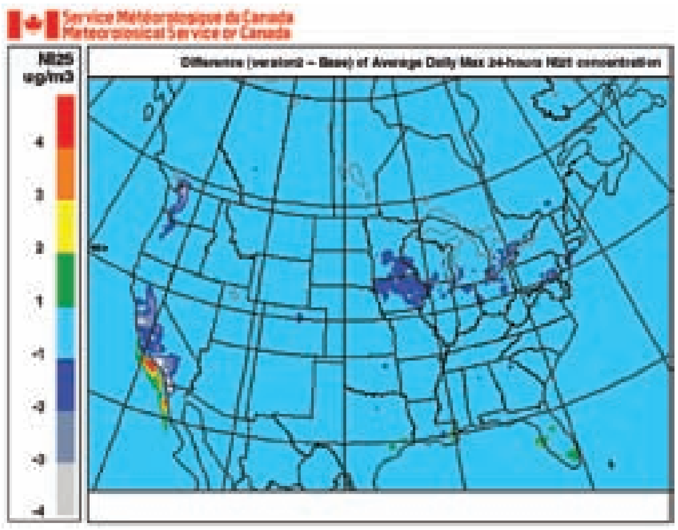
Notes: Top panel: Base case simulation. Middle panel: Difference in number of exceedances between the CC4 simulation and the base case simulation. Bottom panel: Difference in number of exceedances between the CC4b simulation and the base case simulation.

In the CC4 and CC4b simulations, little change was observed overall from the BC simulation (approximately +0.5%). Mean daily maximum 24-hour $PM_{2.5}$ concentrations increased by 1 and 2% (to 9.0 and 9.1 µg/m³) in the CC4 and CC4b simulations, respectively. The duration of the exceedances exhibited a slightly sharper change than mass concentrations, increasing by 6% from the BC simulation to the CC4 simulation, and almost 7% for CC4b simulation. This increase is larger than the increase between the BC and CC4 simulations for O_3 (3.5%), but much smaller than the increase between the BC and the CC4b results (43%).

It is striking that in the CC4 and CC4b simulations, some industrialized and/or urban areas in Canada (particularly the Quebec-Windsor corridor, Winnipeg and southern B.C.) would actually experience a decrease in the percentage of days with average 24-hour $PM_{2.5}$ concentrations exceeding the CWS by 0 to 10%. The small difference between the levels simulated in the CC4 and CC4b simulations suggests that $PM_{2.5}$ levels show very little response to a change in biogenic emissions. Based on the current limited understanding of how biogenic VOCs produce $PM_{2.5}$ (Pun et al., 2002; Aw and Kleeman, 2003) and the current results, $PM_{2.5}$ levels appear not to be strongly influenced by such factors. Changes observed in $PM_{2.5}$ levels between the BC simulation and the CC4 and CC4b simulations may relate to a change in the chemistry of the sulphate–nitrate–ammonium–water system that controls a large fraction of PM mass. Figure 4.11

presents the difference in particle nitrate (NO_3^-) concentration during the summer between the BC and CC4b simulations. Certain regions would experience a decrease in particulate NO_3^- concentration whereas others would see an increase. Patterns of particulate NO_3^- change match those of $PM_{2.5}$.

Figure 4.11 Difference between the base case and CC4b simulations of the NO_3^- fraction of $PM_{2.5}$ during the summer



Decreasing particulate NO_3^- levels with increasing temperature have been observed in other studies. Aw and Kleeman (2003) conducted a similar analysis of the effect of temperature variability on levels of O_3 and $PM_{2.5}$. They found that for some locations, in particular regions that had similar concentrations of gas-phase NH_3 and nitric acid (HNO_3), and especially those with relatively high initial temperatures, particulate NO_3^- concentrations decreased with increasing temperature.

Increasing temperature produces a net effect of two opposing processes: (1) increasing the rate of reaction by which particles are formed (thereby increasing particle concentration) and (2) increasing the volatility of the semi-volatile components of $PM_{2.5}$ (thereby decreasing particle formation). Aw and Kleeman (2003) found that, among regions with high concentrations of gas-phase NH_3 and relatively low initial temperatures, particulate NO_3^- concentrations were less sensitive to an increase in temperature, and minor reductions or sometimes small increases in particulate ammonium nitrate (NH_4NO_3) concentration were observed. However, the work of Aw and Kleeman (2003) was limited geographically to the South Coast Basin surrounding Los Angeles, California. In this area, particles of ammonium nitrate dominate the $PM_{2.5}$ mass fraction, and changes in the concentration of secondary sulphate aerosols in this region had a negligible effect on the observed change in $PM_{2.5}$ mass. In regions where SO_2 emissions are larger, such as eastern Canada and the eastern U.S., Aw and Kleeman (2003) suggested that increased temperatures would lead to higher particulate sulphate concentrations and a reduction in particulate NO_3^-. However, even for the short period analyzed in this study it seems that the decreases in particulate NO_3^- levels are large enough to drive the observed changes in $PM_{2.5}$ mass.

4.5 ESTIMATION OF HUMAN HEALTH IMPACTS ASSOCIATED WITH CHANGES IN AMBIENT AIR QUALITY DUE TO CLIMATE CHANGE

Modelling was undertaken to explore the potential health impacts and associated costs that could result from changes in the atmospheric concentration of O_3 and $PM_{2.5}$ in a warmer climate. Estimates were obtained by comparing modelled air quality during three summer months of the year 2002 (base year) with modelled O_3 and $PM_{2.5}$ conditions that could prevail in North America if the average ambient temperature was 4°C higher. Changes in ambient concentrations associated with increased biogenic emissions of VOCs were also obtained. This exercise made use of Health Canada's Air Quality Benefit Assessment Tool (AQBAT) for characterizing human health risks. A detailed description of AQBAT, including its inputs and outputs is provided in Annex 3. The AQBAT analysis here is based on air pollution concentrations overall, not solely on locations that exceeded the CWS.

Valuation of health impacts of air quality changes (positive or negative) is usually completed to complement cost estimates of air pollution mitigation measures. Such a cost-benefit analysis provides a value estimate of the health benefits compared to the cost of specific pollution management measures. The effects estimated in the current analysis are not complemented with an estimation of the mitigation cost of climate change or GHGs, which is beyond the scope of this Assessment. However, it provides an indication of the impacts Canadian society would face if temperatures rose by 4°C, with anthropogenic emissions of air contaminants held constant at 2002 levels.

The precise nature of the potential health impacts is difficult to assess because such quantification requires the integration of multiple variables, including human behaviour, changes in emissions and other climate variables. The estimation of the effect of climate change on both ozone and $PM_{2.5}$ is complex and depends on multiple variables. While the relationships with ozone are relatively well understood, those with PM are still the subject of much investigation, and these results should stimulate additional research. Overall, climate change, according to the CC4b (temperature and biogenic increases) scenario, was predicted to result in a 4.6% increase in cost to Canadian society.

4.5.1 Estimated Health Benefits: Incremental Climate Change Scenario

The estimated human health impacts of changes from baseline levels of O_3 and $PM_{2.5}$ concentrations to levels projected under scenario CC4b (+4°C and increased biogenic emissions) are presented in Annex 4, Tables 4.6 to 4.8. The CC4 temperature-only results are presented in Tables 4.3 to 4.5.

The national average 8-hour O_3 concentration was increased in the CC4b scenario by 14.7%, whereas the 24-hour $PM_{2.5}$ concentration was reduced by 10.5%. The estimated increase in O_3-related mortality in the CC4b scenario is 658 deaths over the modelled 3-month period, with an associated cost of over \$3 billion (Table 4.6). The increase in the number of Acute Respiratory Symptom Days (ARSD) corresponds to 2,940,278 cases and a cost of over \$42 million. Overall, the total cost of increasing O_3 levels under this scenario is \$3.167 billion. Given the results of the modelling runs, this is primarily associated with temperature-induced biogenic increases rather than a direct temperature effect on ozone formation.

The modelled reduction in $PM_{2.5}$ is associated with decreases in all health endpoints, including a reduction of 346 premature deaths and 810,934 ARSD under the CC4b scenario for the 3-month period in question (Table 4.7). The overall benefit of $PM_{2.5}$ reduction corresponds to reduced costs of $1.8 billion. Based on the modelling runs, the PM results are relatively insensitive to the biogenic changes, and are more directly tied to the temperature increase than was the case with O_3. Given the considerable uncertainty attached to this aspect of the modelling, more research is required to provide greater confidence in both the direction and magnitude of the change in PM levels.

The overall pollutant effect in scenario CC4b is endpoint-dependent because there are increases in the incidence of some endpoints and decreases in others (Table 4.8). Overall, premature mortality would be increased by 312 deaths and significant increased morbidity of several types would be observed, whereas the number of adult chronic bronchitis cases would be reduced by 450. Other health benefits include 20 fewer cardiac emergency room visits, 54 fewer cardiac hospital admissions, and 3,479 fewer child acute bronchitis episodes. The overall cost to society would be approximately $1.4 billion over the modelled 3-month period.

4.5.2 Climate Associated Air Quality Impacts in Perspective

An estimation of the amount of illness and death that could be prevented in the complete absence of ambient levels of O_3 and $PM_{2.5}$ was also calculated. This calculation was performed to put into perspective the increase of illness and death associated with the climate change scenario. This estimate was produced by setting O_3 and $PM_{2.5}$ concentrations to zero and then estimating the differences to the baseline and climate change scenarios.

The average baseline morbidity and mortality estimates associated with O_3 and $PM_{2.5}$, based on comparisons with the zero-pollutant scenario, are provided in Annex 4, Tables 4.9 and 4.10, respectively. The AQBAT simulations indicated an increase from baseline in the incidence of O_3-related morbidity and mortality that ranged from 4.4 to 5.3% for the CC4 scenario. The range for the CC4b scenario was 19.5 to 23.3%. In other words, the inclusion of biogenic emissions resulted in considerably higher incidences of health impacts.

Inclusion of the biogenic component had the opposite effect on PM. Temperature increase alone significantly reduced PM impacts (15.3 to 19.1%) though this result was tempered by inclusion of associated biogenic processes (11.9 to 15.3%).

These results indicate that while these pollutants appear to operate in opposite directions under the influence of climate change, the increase in O_3 formation would result in negative net health impacts overall. This result is most influenced by biogenic aspects of the air quality modelling, and based on this estimate would result in an approximate 4.6% increase in the air pollutant-related health burden to Canadian society, subject to a 4°C temperature increase with anthropogenic emissions held at 2002 levels. Recall that future changes in anthropogenic emissions due to economic growth, technological change or regulation would also significantly affect air quality, but were not considered in this modelling exercise.

4.6 RISK MANAGEMENT AND ADAPTATION

4.6.1 Norms and Trends

In June, 2000, the Canadian federal, provincial and territorial governments, with the exception of Quebec, agreed on the Canada-wide Standards (CWS) for $PM_{2.5}$ and O_3. The CWS are long-term air quality management goals that seek to minimize the risks these substances pose to human health and the environment. Although the health impacts attributed to PM and O_3 have been observed at very low concentrations, the CWS attempt to balance reducing risks from $PM_{2.5}$ and O_3 exposure with technologically feasible and cost-effective measures to reduce ambient levels of air pollutants (CCME, 2006). Specifically, the CWS numerical targets and timeframes are (Canadian Council of Ministers of the Environment (CCME), 2000):

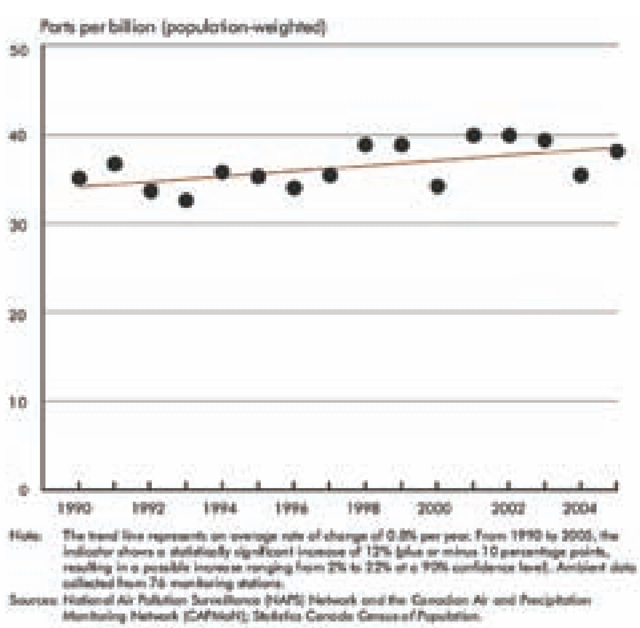
- $PM_{2.5}$: 30 µg/m^3 based on a 24-hour averaging time. Achievement is based on the 98th percentile measurement annually, averaged over 3 consecutive years, by 2010; and
- O_3: 65 ppb based on an 8-hour averaging time. Achievement is based on the fourth highest measurement annually, averaged over 3 consecutive years, by 2010.

In addition to the numerical standards, the CWS also contain provisions that commit jurisdictions to the principles of "Continuous Improvement" and "Keeping Clean Areas Clean." Although the processes governing these two principles have taken some time to elucidate, they are likely to become increasingly important under a warming climate. As larger geographic areas come under the influence of larger and warmer air masses containing air contaminants, those areas currently in marginal compliance with the numerical standards may begin to approach or exceed the CWS.

4.6.1.1 Ground-level ozone

In Canada, population-weighted concentrations of ground-level O_3 have shown a slight increase in recent years (Government of Canada, 2007). Between 1990 and 2005, population-weighted ozone concentrations increased by 12%, with a margin of error of plus or minus ten percentage points (Figure 4.12). O_3 is highest in the Quebec–Windsor corridor, the southern Atlantic region, and to a lesser degree the Lower Fraser Valley of British Columbia.

Figure 4.12 Historical levels of ozone in Canada



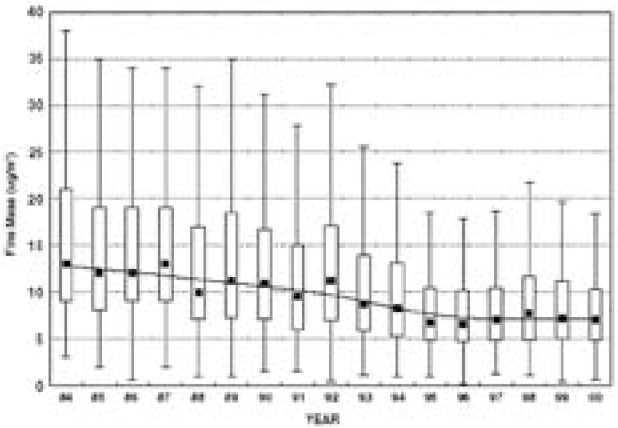
Source: Government of Canada, 2007.

4.6.1.2 Fine particulate matter

Trends in ambient concentrations of $PM_{2.5}$ in Canada are difficult to assess because of changes in monitoring methods over time (Environment Canada, 2003b). Annual averages of $PM_{2.5}$ concentrations for 11 urban sites across Canada are shown in Figure 4.13 (Environment Canada, 2003a). Although there is a slight decreasing trend in mean $PM_{2.5}$ concentration over time, mean levels since the mid-1990s are relatively stable. A large reduction in the value of the 98th percentile is also observed. Such reductions in $PM_{2.5}$ concentrations from the 1980s and early 1990s are likely due to decreases in SO_2 emissions resulting from acid rain prevention programs (Environment Canada, 2004).

More recent reports show that population-weighted levels showed no statistically significant increase or decrease between 2000–2005 (Government of Canada, 2007).

Figure 4.13 Trend in annual mean $PM_{2.5}$ ($\mu g/m^3$), 1984–2000 (10th percentile, 98th percentile and mean)



Source: Environment Canada, 2003a.

4.6.1.3 Canadian sources and transboundary pollution

Several North American airsheds extend beyond national boundaries, resulting in transboundary pollution and air quality problems whereas other areas are dominated by local sources and conditions. Two regions in Canada with considerable transboundary air pollution are the Great Lakes Basin airshed and the Georgia Basin–Puget Sound airshed (Environment Canada, 2004). A recent report, *Transboundary Air Pollution in Ontario* (Yap et al., 2005) documents that, during smog episodes, transboundary air pollution in Ontario reaches or exceeds the levels resulting from local sources. Canada and the United States currently jointly manage aspects of air quality through the Canada-United States Air Quality Agreement (AQA) (Environment Canada, 2006).

4.6.2 Air Quality Index Forecasts and Adaptation

4.6.2.1 The Air Quality Health Index

Air quality forecasts and the publication of current air quality conditions provide the public with opportunities to undertake short-term adaptive measures that reduce their exposure to air pollutants. With air quality indices designed around ambient air quality objectives for individual pollutants, attention is often focussed on the air quality advisories that are issued when these objectives are exceeded. However current scientific evidence shows that health risks increase more or less linearly as air quality deteriorates, and that several pollutants simultaneously contribute to the health risks.

Health Canada and Environment Canada, in conjunction with provinces, municipalities and a variety of stakeholders from the health and environmental communities, have developed a new index that better reflects the immediate health risks associated with the smog mixture. This new Air Quality Health Index (AQHI) was designed to be a personal health protection tool to be used by the public on a daily basis. The AQHI scale is accompanied by health advice targeted to vulnerable groups—children, seniors, and people with cardiovascular and respiratory disease—as well as to the general population, to enable individuals to make informed decisions about reducing their exposure to air pollution and their associated health risks. Several communities have piloted the new index and over the next three years it will be implemented throughout Canada as part of a renewed air quality forecast program. For example, information on the City of Toronto's AQHI can be obtained at www.toronto.ca/health/aqhi/.

4.6.2.2 Outreach to the public, at-risk populations and health professionals

Significant social marketing efforts will be undertaken to make the Air Quality Health Index (AQHI) as effective as the Ultraviolet (UV) Index. For example, the federal government will work in collaboration with the communications industry, including The Weather Network and local media providers, to identify the ideal means of communicating the AQHI to the public through different media (i.e. television, print, radio, automated telephone, Internet). Lessons learned from the 2006 pilots utilizing websites, radio and automated telephone for communicating the AQHI will be taken into consideration. Government On-Line officials will also be engaged to investigate the feasibility of creating a nationally branded federal portal for the index, providing one-stop access to air quality measurements and forecasts via the AQHI in various jurisdictions.

To facilitate education and endorsement of the AQHI by health professionals, Health Canada will develop a toolkit for health professionals based on recent research. The toolkit will detail the health impacts of air pollution, information on how to interpret and explain the AQHI to their patients, and appropriate actions to reduce exposure to air pollution while maintaining a balance of healthy lifestyle factors. Materials will also be generated for health professionals to distribute to their clientele.

Outreach materials will be developed for the general public to provide consistent health and air quality messaging. Additional efforts will concentrate on messaging targeting susceptible populations and their caregivers (children, seniors, and people with cardiovascular and respiratory disease). It is envisioned that these resources will be developed in concert with and distributed by non-governmental organizations as well as health professionals.

4.6.2.3 Links to other adaptation programs

Several communities across Canada have already implemented different types of heat alert systems (see Chapter 8, Vulnerabilities, Adaptation and Adaptive Capacity in Canada) and many more are investigating their applicability in their community. The Government of Canada committed in 2007 to working with stakeholders on developing best practices for the implementation of Heat Alert Systems and Infectious Disease Alert Systems. Lessons learned from the AQHI could provide valuable information to Health Canada's pilot heat alert and response initiative. For example, as is the case with air quality, the most heat-vulnerable groups include seniors, children, and people with pre-existing conditions. The AQHI's communication and outreach methods could prove valuable in designing health messaging around the effects of heat on vulnerable populations.

4.7 DISCUSSION AND CONCLUSIONS

Chapter 4

Overall, results from epidemiological studies have provided some evidence, although sparse, that temperature may influence the impact of air pollution on health. This interaction may be due to true synergistic effects, but other plausible explanations must also be considered. Higher average temperatures are in fact associated with greater exposure to air pollution because population activity patterns change (e.g. people spend more time outside and tend to leave their windows open, though air conditioning may temper this).

Results from atmospheric modelling conducted for this Assessment focussed only on changes in temperature and biogenic emissions, ignoring possible changes in anthropogenic emissions. Nevertheless, modelling has produced a useful basis for future work because the results have suggested that climate change could change the ambient tropospheric levels of O_3 and $PM_{2.5}$. Results have also suggested that increased temperature may lead to increases in O_3 concentrations but decreases in $PM_{2.5}$ concentrations. However, modelling that accounts for all potentially related factors, such as precipitation and anthropogenic emissions is required to adequately assess the direction for $PM_{2.5}$ under warmer climatic conditions.

Modelled changes in air pollutants certainly imply that climate change could lead to increases in illnesses and premature death in Canada. Valuation estimates clearly indicate that climate change would result in increased financial burden over the 3-month summer period, largely due to O_3. A similar assessment for a 12-month period would theoretically result in a larger number, but not necessarily four times larger because the highest air pollution levels are primarily experienced in summer. The results of quantifying the human health impacts with AQBAT clearly suggest that climate change in Canada may result in significant health costs to society.

The scenarios used here are only a first step in improving understanding of the effects of climate change on air quality. Only two factors, temperature and biogenic emissions, of the multitude of the factors that may be affected by climate change were considered. More detailed Global Climate Model, Regional Climate Model, AURAMS and AQBAT assessments might provide more accurate estimates of how climate change might affect air pollution in Canada and its related health impacts.

Future assessments of the potential health impacts related to climate change should integrate the broader chain of events that would likely be involved. More accurate estimations of the potential health effects which take into account population growth and change, the climate for various future time periods (e.g. around the years 2020, 2050 and 2080), anthropogenic and natural emissions, atmospheric modelling, changes in human exposure to pollutants, environmental changes associated with climate change and GHG mitigation measures should be conducted. For instance, changes in weather patterns could modify the energy demands associated with the cooling and heating of buildings, which in turn could result in changes in pollutant emissions. These assessments should also consider the existing disparities in the social, economic and health status of the residents of different provinces and territories. However, they would still leave many uncertainties.

4.8 ANNEXES

Annex 1: Literature Search Methodology

Five bibliographical databases were searched, using several different terms combined in a logical expression, to identify all relevant articles in the published literature (Figure 4.14).

Figure 4.14 Bibliographic databases and search terms and logical expressions used to identify relevant studies in the literature

Databases
Ovid MEDLINE(R) 1966 to June Week 4 2005
Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations July 05, 2005
Biological Abstracts/RRM 1992 to 2002
Biological Abstracts 2002 to June 2005
Current Contents/All Editions 1993 Week 27 to 2005 Week 28

Search terms and logical expression (? and $ denote wildcards)
heat-wave? or heatwave? or (heat wave?)
OR
heat or hot$ or warm$ or (high$ temperature?)
AND
temperature? or weather or meteorolog$ or climat$ or season$
AND
(air pollut$) or (atmospheric pollut$) or "air quality" or ozone
OR
(particles OR particulate) and pollut$
AND
health or morbidity or mortality or death? or admission? or consult$ or disease? or disorder?

This search resulted in over 600 references published by 2006. These were manually selected, based on their title and abstract, resulting in approximately 50 core articles. Several other key articles cited as references to these papers or found elsewhere were added to the list. All articles were then reviewed, and if deemed relevant, were classified and retained for analysis.

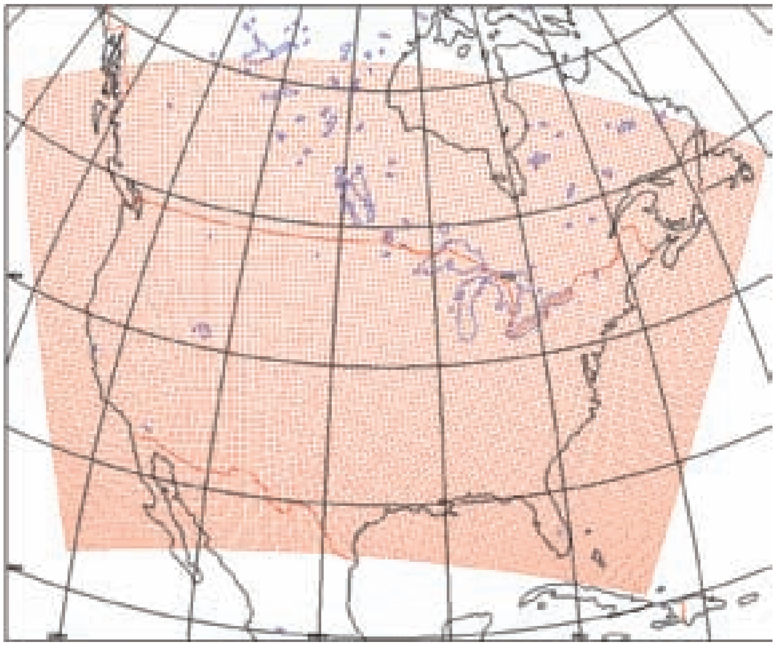
Annex 2: AURAMS Model

1. Model Description

A Unified Regional Air-quality Modelling System (AURAMS) is a unified regional air quality modelling system developed by Environment Canada for research and policy applications. Designed as a "one-atmosphere" system, AURAMS allows the study of interactions between NOx, VOCs, NH_3, O_3, and primary and secondary airborne PM smaller than 2.5 µm ($PM_{2.5}$). It can therefore be used to address a variety of interconnected tropospheric air pollution problems ranging from surface O_3 to acid rain to PM over the entire North American continent.

AURAMS has been exercised over domains covering the whole or parts of the North American continent at spatial resolutions of 20 to 42 km (Figure 4.15). Although initial applications of AURAMS were limited to episodic events, it is now being used for seasonal and annual simulations, as well as in experimental mode for next-day forecasting of air quality. Evaluations of the performance of AURAMS can be found in the peer-reviewed literature (Bouchet et al., 2003; Gong et al., 2003b; Makar et al., 2004; McKeen et al., 2005; Gong et al., 2006) and in recent joint U.S.and Canada assessments (Canada-U.S. Subcommittee on Scientific Co-operation, 2004). For determination of O_3 and PM concentrations for the present study, AURAMS was run at 42-km resolution on a continental domain.

Figure 4.15 AURAMS modelling domains in North America



The three major components of the system, namely the meteorological driver, the emission processor and the chemical transport model, are described below. Additional details on the various processes represented in the chemical transport model are also given.

2. Meteorological Component

AURAMS is driven "off-line" by the Canadian operational forecast model, Global Environmental Multiscale model (GEM). GEM is a non-hydrostatic, two-time-level implicit semi-Lagrangian model (Côté et al., 1998a, 1998b). For air quality applications, meteorological fields from a high-resolution regional window positioned over the air quality modelling domain are stored at the frequency required by the AURAMS (i.e. 900 seconds), then interpolated spatially to match the grid used by the air quality model.

3. Emission Components

Anthropogenic emission component

Hourly point-, area- and mobile-source emissions files are prepared by the Spare-Matrix Operating Kernel Emissions processor (SMOKE), from the year 2000 Canadian and the year 2001 U.S. national criteria-air-contaminant emission inventories for the AURAMS domain. The total Canadian anthropogenic emissions for the year 2000 are presented in Table 4.1. Similar information for the year 2001, which is stored in the U.S. national emission inventory, can be readily accessed online. AURAMS-ready emission fields include 17 gas-phase species, as well as primary $PM_{2.5}$ and PM_{10} emissions. Within the AURAMS chemical transport component, PM emissions are disaggregated according to size and chemical species as a function of the source stream. A plume-rise calculation is also applied to major point sources. Two other types of emissions are represented online in AURAMS: biogenic emissions using the Biogenics Emissions Inventory System, Version 3.09 (BEISv3.09) algorithm and sea salt emissions from wave-breaking (Gong et al., 2003a).

Table 4.1 Total Canadian anthropogenic emissions (in tons) from area, mobile and non-road sources for the year 2000

	Area*	Mobile†	Non-Road‡
TPM	17,490,531	21,242	69,771
PM_{10}	105,311,545	21,162	68,787
$PM_{2.5}$	842,433	19,415	60,102
SO_2	202,559	28,005	63,323
NO_x	435,225	936,794	774,694
VOC	1,938,958	446,438	354,872
CO	1,870,862	6,313,751	2,915,483
NH_3	591,966	19,695	998

* In this table, includes industrial sources and small, non-mobile sources that are inventoried as a group (e.g. wood stoves and incinerators).

† Cars, trucks and other on-road mobile sources.

‡ Off-road mobile sources like tractors and backhoes.

Biogenic emission component

Plants emit VOCs that can serve as precursors of O_3 and of $PM_{2.5}$ by reacting in the atmosphere with other chemicals such as NOx, or with solid or semi-solid particles. These VOCs include isoprene and methyl butanol, whose highest concentrations occur in the air above large forests and above extensive agricultural crops. The biogenic emissions inventory module BEISv3.09, developed in the U.S. by a U.S. Environmental Protection Agency–National Oceanic and Atmospheric Administration partnership (U.S. EPA 2006b, 2006c), was used within AURAMS to estimate biogenic VOC emissions from vegetation and NO emissions from soil.

AURAMS chemical transport model

The AURAMS chemical transport component includes a representation of all the processes that influence the formation, release and fate of O_3 and PM. Up to eight chemical components are considered to contribute to PM composition: sulphate, nitrate, ammonium, black carbon, primary organic carbon, secondary organic carbon, crustal material and sea salt. These PM chemical components are assumed to be internally mixed in each of the 12 size bins of the PM sectional size distribution, spanning diameters between 0.01 µm and 40.96 µm. No data assimilation is performed in AURAMS.

AURAMS uses a non-oscillatory semi-Lagrangian advection scheme (Pudykiewicz et al., 1997; Sirois et al., 1999) to describe the transport of up to 145 individual chemical tracers. The gas-phase mechanism is a modified version of the ADOM-II mechanism (Stockwell and Lurmann, 1989) and incorporates 42 gas-phase species and 114 reactions based on Lurmann et al. (1986). It has been extended to include secondary organic aerosol formation based on the approach of Jiang (2003), inorganic heterogeneous chemistry (i.e. gas-particle partitioning of the sulphate–nitrate–ammonium–water system) (Makar et al., 2003), and aqueous-phase chemistry based on a modified ADOM mechanism coupled with explicit aerosol components. Aerosols are represented by a size-segregated multi-component algorithm (the Canadian Aerosol Module (CAM)) (Gong et al., 2003a). CAM relies on a sectional approach, and includes major aerosol processes in the atmosphere: generation, hygroscopic growth, coagulation, nucleation, condensation, dry deposition and sedimentation, below-cloud scavenging as well as aerosol activation. Finally, dry deposition of gases and size-dependent aerosols is based on the resistance approach (Zhang et al., 2001, 2002), and wet deposition processes to gases and aerosol include cloud-to-rain conversion and below-cloud scavenging as well as evaporation (Gong et al., 2003b).

Annex 3: AQBAT Model

1. Model Description

The Air Quality Benefits Assessment Tool (AQBAT) is a computer simulation tool designed to estimate the relative human health and welfare benefits or risks associated with changes in Canada's ambient air quality. AQBAT allows users to define a wide range of specific scenarios by combining and linking various air pollutants, health endpoints, geographic areas and scenario years. AQBAT can provide economic valuation estimates based on changes in the incidence of health impacts associated with changes in air quality. AQBAT is the successor to the Air Quality Valuation Model (AQVM). It consists of one Excel file containing Excel user forms and toolbars with numerous controls, and Visual Basic programming to help the user define, run, examine and save a specific scenario. An expert panel of the Royal Society of Canada reviewed socio-economic analysis tools and provided specific comments on AQVM, the predecessor of AQBAT. The expert panel supported AQVM and the inputs used in the model (Royal Society of Canada, 2001).

AQBAT contains files of historical and projected population data, and can access preset data files of historical and hypothetical pollutant concentrations, as well as baseline health endpoint rates. The model utilizes and controls the @Risk (trademark) add-in software to perform Monte Carlo simulations, which entail sampling the input distributions, tracking the calculated sample outputs, and providing descriptive statistics on the distributions of these outputs.

2. AQBAT Approach

The net risk or benefit associated with changes in the ambient air pollutant concentration is estimated using concentration response functions (CRF) that are assigned to specific pollutant concentrations and to exposed populations. The AQBAT user defines a CRF for a pollutant-health endpoint combination and assigns it to one or more geographic areas. Different geographic areas may be assigned either the same quantified impact of a pollutant on a health endpoint, or different ones (i.e. there can be multiple CRFs for the same pollutant-health endpoint combination). Each CRF applies to every year of the scenario.

The count estimate formulation, in its simplified form, consists of multiplying the following factors:

- CRF expressed as % excess adverse endpoints per unit concentration increase of pollutant;
- pollutant concentration change as the difference between the status quo and forecast concentrations;
- baseline rate of incidence of the health endpoint in the target population; and
- target population count.

These counts are derived for individual scenario years.

3. Concentration Response Function

The CRF is a quantification of the impact of an air pollutant on a health endpoint. It is a statistically derived estimate of the percent excess health endpoint associated with a unit increase in the pollutant concentration. It is generally derived from a statistical model, or from the pooling of estimates from several models or studies. CRFs therefore have an

uncertainty in their quantification, reflected in the selection of a distribution form (normal, triangular or 3-point discrete), with corresponding parameter inputs in AQBAT. During a scenario model simulation run, the @Risk tool samples these distribution functions, from which output sample values are calculated and tracked; these outputs therefore have a distribution themselves. There are 13 different health endpoints in this model:

Acute Exposure Mortality

Acute Respiratory Symptom Days

Adult Chronic Bronchitis Cases

Asthma Symptom Days

Cardiac Emergency Room Visits

Cardiac Hospital Admissions

Child Acute Bronchitis Episodes

Chronic Exposure Mortality

Elderly Cardiac Hospital Admissions

Minor Restricted Activity Days

Emergency Room Visits Due to Respiratory Illnesses

Hospital Admissions Due to Respiratory Illnesses

Days of Restricted Activity

Each of these represents a health endpoint resulting either from an acute or short-term exposure, or from a long-term or chronic exposure (see Table 4.13 for all CRFs). As well, each of these endpoints corresponds to a certain proportion of a specific population age group. These characteristics of the health endpoints are pre-defined in AQBAT; the user cannot change them.

4. Economic Valuation Estimates

Economic valuation estimates for health outcomes consider potential economic and social consequences associated with the adverse health impacts that result from air pollution, including medical costs, work loss, out-of-pocket expenses, and pain and suffering. Although the economic valuation estimates used to assess potential benefits may include medical costs, they must not be interpreted in their totality as savings to the health care system. The valuation estimates must be considered merely as an indication of the relative value that society places on health benefits represented by decreases in the risk of death or disease (see Table 4.12 for AQBAT valuation information).

One economic measure of value that represents the reasons why people desire reductions in health risks is called "willingness to pay." Willingness to pay is a measure of the monetary tradeoffs that people are willing to make in exchange for reductions in risks of mortality or morbidity. Unlike many goods and services that Canadians can purchase and enjoy, the prevention of health risks cannot be directly purchased in the marketplace. Therefore, there are no price and quantity data from which the economic values can be easily estimated.

Over the last five decades, economists have developed and refined a number of techniques to estimate the economic value of avoiding adverse health impacts. These techniques estimate values by examining how people would trade money for reductions in health risks. There are a number of empirical methods for valuation; these essentially fall into two categories—those that rely on observed market behaviour ("revealed preference methods") and those that do not ("stated preference methods").

5. Netting

Netting is the subtraction of one health endpoint count from another health endpoint count (see under section 8, Outputs, later in Annex 3 for a discussion of counts), because the former endpoint may overlap with the latter. The result of not carrying out the netting may be a double counting of the latter endpoint. One common example of netting is that Respiratory Hospital Admissions (RHAs) are subtracted from Respiratory Emergency Room Visits (RERVs), under the assumption that some RHAs started out as RERVs. In this example, not carrying out the subtraction would result in some RHAs being counted as both health endpoints. The netting results in conservative estimates. The user can decide whether a CRF is already netted, or alternatively, whether AQBAT is to apply the preset netting adjustments to the health endpoint counts that result in applying the scenario model CRFs.

6. Grouping

Grouping is the accumulation of similar health endpoints. Acute Exposure Mortality counts and Chronic Exposure Mortality counts are usually added up to obtain total mortality counts. This could be done outside of AQBAT after the simulation has been run, but grouping during the simulation reduces the workload for the user. As well, grouping during the simulation produces exact percentile values for the distributions of grouped endpoint outputs, whereas these can be approximated only outside the simulation. However, grouping during the simulation requires tracking more outputs, and therefore, a longer run time for the simulation.

7. Geographic Areas

AQBAT was developed for Canada's geography. There are 442 geographic areas in the current version of AQBAT, based on the 2001 Census Geography as determined by Statistics Canada. Each of the 442 geographic areas is one or two of the following five types by level (acronym and/or count):

- National level: Canada as a whole
- Provincial level: provinces or territories (13)
- Specific (lowest) level: Census Agglomeration Area (CA, 113), Census Metropolitan Area (CMA, 27), and Census Division (CD, 288)

Census Agglomeration Areas (CAs) are towns with a total population between 10,000 and 100,000 and Census Metropolitan Areas (CMAs) are cities with a total population of 100,000 or more.

8. Outputs

AQBAT provides estimates of excess or reduced health endpoints in a geographic area that is associated with an inputted pollutant concentration change. The CRF has an uncertainty and is input into AQBAT as a distribution function. The pollutant concentration change, the baseline rates of health endpoints and the population count are deterministic, based on specific choices or inputs to define the scenario model in AQBAT. The resulting output count therefore also has an uncertainty, expressed as a distribution. There are two additional scenario model output types: percent of baseline and economic valuations. Both of these use the counts as a factor in their calculation.

AQBAT allows for the generation of up to 20,000 outputs, tracked by @Risk during the simulation; one iteration results in a sampled value for each tracked output. Percentile values, means, standard deviations and other statistics are determined from the simulation for each set of output sample values. For each output, the user can examine the distribution of values on a chart. There are tools available in AQBAT to filter or "home in" on a smaller subset of outputs, when necessary. All inputs defining the specific scenario model, along with the output distributions can also be stored in an external Excel workbook for investigation and analysis outside of AQBAT.

9. Definition of the AQBAT Estimates

The atmospheric modelling for O_3 and $PM_{2.5}$ was carried out by scientists at Environment Canada to estimate average air pollutant concentrations in 2,446 Census Consolidated Subdivisions (CCSs) (of the census year 2001) during the months of June, July and August 2002. These concentration levels were then averaged over all CCSs in a Census Division (CD), to determine a concentration level for each of the 288 CDs under the corresponding hypothesis. AQBAT estimates were based on a modelled baseline and a scenario where ambient temperature was increased by 4°C without changes in biogenic emissions of air pollutant precursors (scenario CC4) and a scenario where ambient temperature was increased by 4°C with associated changes in biogenic emissions (scenario CC4b). These estimates were used as an indication of the potential health impacts of these two climate change scenarios (CC4 and CCC4b). AQBAT estimates of the differences between the CC4 and CC4b scenarios were also used to show the effect of biogenic emissions.

AQBAT estimates of the differences between a scenario in the absence (anthropogenic and biogenic) of air pollutants (Zero) and baseline, CC4 and CC4b scenarios were completed. These estimates were obtained to put into perspective the various estimates against the overall mortality and morbidity associated with air pollutants. AQBAT estimates for the environmental states identified in Table 4.2 were obtained.

Table 4.2 The six estimates computed as part of this project

AQBAT Estimates	Baseline State	Compared to
1	Baseline	CC4
2	Baseline	CC4b
3	CC4	CC4b
4	Zero	Baseline
5	Zero	CC4
6	Zero	CC4b

It should be noted that the AQBAT estimates for the current project are for a 3-month summer period, as the atmospheric modelling for this project covered only the months of June, July and August 2002. Adjustment to the baseline mortality or morbidity rates was completed to report the results for the 3-month period only. Using 2002 as a base year for the simulations means that the meteorological inputs are generated for summer 2002. Although no single summer can really represent the climate average, the only alternative to performing years of simulation is to choose a base year that is as representative as possible of that average (see section 4.4.1 for additional details).

10. AQBAT Results

AQBAT estimates were generated nationally and for each of the provinces and territories as well as for each of the CDs with a population of more than 200,000 people. Twenty thousand @Risk iterations were completed for each analysis. Results are provided individually for each of the two pollutants, and the overall effect is also provided separately. Absolute estimates and the valuation associated with each of the health endpoints are provided in each table of results in Annex 4. The list of endpoints for each of the pollutants differs somewhat, as the health impacts of O_3 and $PM_{2.5}$ are not identical.

It is important to remember that AQBAT estimates cover only the months of June, July and August. These estimates would likely be higher if computed for a 12-month period, but would not necessarily be four times higher as this project covers the predominant period for smog events.

Some may argue that chronic health impacts should not be part of the Assessment as only a 3-month period was modelled. However, the analysis is used as an indication of the long-term trend in the potential shift in air pollution as indicated by one segment (June, July and August) and is therefore representative of the potential impacts on chronic health impacts that would be observed over the long term.

Some values are truncated at Zero because the developers of AQBAT concluded that pollution associated with O_3 and PM could not result in positive effects to human health.

Annex 4: Detailed AQBAT Results, Valuation Information and Concentration Response Functions

Table 4.3 O_3: AQBAT estimates from baseline to scenario CC4, national data

Endpoint		Absolute Changes from Baseline Mean (95% CI*)
Acute Exposure Mortality	Count Valuation	-156 (-207, -105) -$726,056,312 (-$1,653,546,752, -$311,456,512)
Acute Respiratory Symptom Days	Count Valuation	-696,586 (-1,607,940, 0) -$10,153,797 (-$37,319,304, $0)
Asthma Symptom Days	Count Valuation	-92,291 (-150,091, -34,619) -$5,148,005 (-$12,521,288, -$1,129,731)
Minor Restricted Activity Days	Count Valuation	-201,800 (-87,599, 0) -$7,921,113 (-$40,626,480, $0)
Respiratory Emergency Room Visits	Count Valuation	-374 (-783, 0) -$147,277 (-$328,433, $0)
Respiratory Hospital Admissions	Count Valuation	-92 (-172, -11) -$421,657 (-$831,809, -$49,016)
Acute Exposure Mortality + Chronic Exposure Mortality	Count Valuation	-156 (-207, -105) -$726,056,312 (-$1,653,546,752, -$311,456,512)
Cardiac Hospital Admissions + Respiratory Hospital Admissions	Count Valuation	-92 (-172, -11) -$421,657 (-$831,809, -$49,016)
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	Count Valuation	-374 (-783, 0) -$147,277 (-$328,443, $0)
All Endpoints	Count Valuation	Not applicable -$749,848,162 (-$1,678,030,080, -$333,939,776)

Note: A negative value represents a negative effect to society and should therefore be considered as an increase in cost or health impacts. A positive value represents a positive effect to society and should therefore be considered as a reduction in cost or health impacts.

* CI, Confidence Interval

Table 4.4 $PM_{2.5}$: AQBAT estimates from baseline to scenario CC4, national data

Endpoint		Absolute Changes from Baseline Mean (95% CI)
Acute Respiratory Symptom Days	Count Valuation	1,010,696 (0, 2,602,081) $14,691,284 ($0, $57,391,520)
Adult Chronic Bronchitis Cases	Count Valuation	559 (0, 1106) $184,819,544 ($0, $487,192,096)
Asthma Symptom Days	Count Valuation	40,878 (9827, 71,808) $2,279,833 ($332,484, $5,871,109)
Cardiac Emergency Room Visits	Count Valuation	24 (0, 65) $9,646 ($0, $26,454)
Cardiac Hospital Admissions	Count Valuation	68 (36, 99) $383,991 ($182,677, $625,964)
Child Acute Bronchitis Episodes	Count Valuation	4,298 (0, 9,159) $1,470,337 ($0, $4,073,960)
Chronic Exposure Mortality	Count Valuation	428 (227, 629) $1,995,154,492 ($718,112,448, $4,843,215,872)
Respiratory Emergency Room Visits	Count Valuation	176 (100, 253) $69,460 ($34,899, $110,597)
Respiratory Hospital Admissions	Count Valuation	44 (29, 58) $200,064 ($182,240, $296,629)
Restricted Activity Days	Count Valuation	620,980 (366,139, 874,903) $32,435,121 ($0, $71,797,136)
Acute Exposure Mortality + Chronic Exposure Mortality	Count Valuation	428 (227, 629) $1,995,154,492 ($718,112,448, $4,843,215,872)
Cardiac Hospital Admissions + Respiratory Hospital Admissions	Count Valuation	111 (76, 146) $584,055 ($365,122, $840,583)
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	Count Valuation	201 (115, 291) $79,107 ($40,695, $123,901)
All Endpoints	Count Valuation	Not applicable $2,231,513,773 ($929,518,016, $5,080,671,744)

Note: A negative value represents a negative effect to society and should therefore be considered as an increase in cost or health impacts. A positive value represents a positive effect to society and should therefore be considered as a reduction in cost or health impacts.

Table 4.5 Both pollutants: AQBAT estimates from baseline to scenario CC4, national data

Endpoint		Absolute Changes from Baseline Mean (95% CI)
Acute Exposure Mortality	Count Valuation	-156 (-207, -105) -$726,056,312 (-$1,653,546,752, -$311,456,512)
Acute Respiratory Symptom Days	Count Valuation	314,110 (-1,233,611, 2,119,159) $4,537,487 (-$24,191,136, $43,016,324)
Adult Chronic Bronchitis Cases	Count Valuation	559 (0, 1106) $184,819,544 ($0, $487,192,096)
Asthma Symptom Days	Count Valuation	-51,413 (-116,874, 14,486) -$2,868,172 (-$8,925,413, $702,022)
Cardiac Emergency Room Visits	Count Valuation	24 (0, 74) $9,646 ($0, $30,420)
Cardiac Hospital Admissions	Count Valuation	68 (36, 99) $383,991 ($182,677, $625,964)
Child Acute Bronchitis Episodes	Count Valuation	4,298 (0, 9159) $1,470,337 ($0, $4,073,960)

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Endpoint		Absolute Changes from Baseline Mean (95% CI)
Chronic Exposure Mortality	Count Valuation	428 (227, 629) $1,995,154,492 ($718,112,448, $4,843,215,872)
Minor Restricted Activity Days	Count Valuation	-201,800 (-873,599, 0) -$7,921,113 (-$40,626,480, $0)
Respiratory Emergency Room Visits	Count Valuation	-198 (-616, 184) -$77,817 (-$252,547, $73,374)
Respiratory Hospital Admissions	Count Valuation	-48 (-130, 33) -$221,593 (-$617,189, $153,411)
Restricted Activity Days	Count Valuation	620,980 (336,139, 874,903) $32,435,121 ($0, $71,797,136)
Acute Exposure Mortality + Chronic Exposure Mortality	Count Valuation	272 (64, 481) $1,269,098,181 (-$402,231,328, $4,193,872,384)
Cardiac Hospital Admissions + Respiratory Hospital Admissions	Count Valuation	19 (-69, 105) $162,398 (-$289,217, $594,437)
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	Count Valuation	-173 (-591, 210) -$68,171 (-$243,020, $85,423)
All Endpoints	Count Valuation	Not applicable $1,481,665,612 (-$198,432,752, $4,416,672,768)

Note: A negative value represents a negative effect to society and should therefore be considered as an increase in cost or health impacts. A positive value represents a positive effect to society and should therefore be considered as a reduction in cost or health impacts.

Table 4.6 O_3: AQBAT estimates from baseline to scenario CC4b, national data

Endpoint		Absolute Changes from Baseline Mean (95% CI)
Acute Exposure Mortality	Count Valuation	-658 (-876, -442) -$3,065,838,265 (-$6,989,489,664, -$1,324,193,408)
Acute Respiratory Symptom Days	Count Valuation	-2,940,278 (-6820468, 0) -$42,578,915 (-$155,551,872, $0)
Asthma Symptom Days	Count Valuation	-394,438 (-644,376, -147,054) -$22,064,012 (-$54,112,592, -$4,533,992)
Minor Restricted Activity Days	Count Valuation	-871327 (-3,816,480, 0) -$34,602,731 (-$179,627,168, $0)
Respiratory Emergency Room Visits	Count Valuation	-1,558 (-3,282, 0) -$613,496 (-$1,381,587, $0)
Respiratory Hospital Admissions	Count Valuation	-382 (-719, -46) -$1,756,359 (-$3,479,363, -$206,747)
Acute Exposure Mortality + Chronic Exposure Mortality	Count Valuation	-658 (-876, -442) -$3,065,838,265 (-$6,989,489,664, -$1,324,193,408)
Cardiac Hospital Admissions + Respiratory Hospital Admissions	Count Valuation	-382 (-719, -46) -$1,756,359 (-$3,479,363, -$206,747)
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	Count Valuation	-1,558 (-3,282, 0) -$613,496 (-$1,381,587, -$0)
All Endpoints	Count Valuation	Not applicable -$3,167,453,777 (-$7,102,102,016, -$1,420,562,304)

Note: A negative value represents a negative effect to society and should therefore be considered as an increase in cost or health impacts. A positive value represents a positive effect to society and should therefore be considered as a reduction in cost or health impacts.

Table 4.7 $PM_{2.5}$: AQBAT estimates from baseline to scenario CC4b, national data

Endpoint		Absolute Changes from Baseline Mean (95% CI)
Acute Respiratory Symptom Days	Count Valuation	810,934 (-1, 208,7633) $11,786,653 ($0, $46,570,748)
Adult Chronic Bronchitis Cases	Count Valuation	450 (0, 892) $149,476,645 ($0, $396,918,784)
Asthma Symptom Days	Count Valuation	32,817 (7,890, 57,660) $1,835,379 ($274,370, $4,700,622)
Cardiac Emergency Room Visits	Count Valuation	162 (92, 233) $63,595 ($32,510, $99,810)
Cardiac Hospital Admissions	Count Valuation	54 (29, 80) $309,809 ($145,737, $504,069)
Child Acute Bronchitis Episodes	Count Valuation	3,479 (0, 7,450) $1,186,541 ($0, $3,302,251)
Chronic Exposure Mortality	Count Valuation	346 (183, 509) $1,610,567,933 ($589,880,640, $3,874,233,856)
Respiratory Emergency Room Visits	Count Valuation	142 (80, 204) $55,795 ($27,981, $88,450)
Respiratory Hospital Admissions	Count Valuation	35 (23, 47) $160,722 ($95,211, $237,069)
Restricted Activity Days	Count Valuation	498,629 (293,856, 702,787) $26,020,581 ($0, $57,630,600)
Acute Exposure Mortality + Chronic Exposure Mortality	Count Valuation	346 (183, 509) $1,610,567,933 ($589,880,640, $3,874,233,856)
Cardiac Hospital Admissions + Respiratory Hospital Admissions	Count Valuation	89 (61, 118) $470,531 ($289,620, $675,508)
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	Count Valuation	162 (92, 233) $63,595 ($32,510, $99,810)
All Endpoints	Count Valuation	Not applicable $1,801,407,857 ($751,893,632, $4,075,342,080)

Note: A negative value represents a negative effect to society and should therefore be considered as an increase in cost or health impacts. A positive value represents a positive effect to society and should therefore be considered as a reduction in cost or health impacts.

Table 4.8 Both pollutants: AQBAT estimates from baseline to scenario CC4b, national data

Endpoint		Absolute Changes from Baseline Mean (95% CI)
Acute Exposure Mortality	Count Valuation	-658 (-876, -442) -$3,065,838,265 (-$6,989,489,664, -$1,324,193,408)
Acute Respiratory Symptom Days	Count Valuation	-2,129,344 (-6,178,484, 1,332,933) -$30,792,263 (-$136,676,912, $21,992,590)
Adult Chronic Bronchitis Cases	Count Valuation	450 (0, 892) $149,476,645 ($0, $396,918,784)
Asthma Symptom Days	Count Valuation	-361,620 (-612,340, -112,404) -$20,228,634 (-$50,705,608, -$3,634,177)
Cardiac Emergency Room Visits	Count Valuation	20 (0, 60) $7,800 ($0, $24,460)

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Endpoint		Absolute Changes from Baseline Mean (95% CI)
Cardiac Hospital Admissions	Count Valuation	54 (29,80) $309,809 ($145,737, $504,853)
Child Acute Bronchitis Episodes	Count Valuation	3,479 (0, 7,450) $1,186,541 ($0, $3,320,251)
Chronic Exposure Mortality	Count Valuation	346 (183, 509) $1,610,567,933 ($589,880,640, $3,874,233,856)
Minor Restricted Activity Days	Count Valuation	-871,327 (-3,816,480, 0) -$34,602,731 (-$179,627,168, $0)
Respiratory Emergency Room Visits	Count Valuation	-1,416 (-3,146,134) -$557,701 (-$1,315,710, $52,460)
Respiratory Hospital Admissions	Count Valuation	-347 (-684, -11) -$1,595,637 (-$3,295,326, -$46,996)
Restricted Activity Days	Count Valuation	498,629 (293,856, 702,787) $26,020,581 ($0, $57,630,600)
Acute Exposure Mortality + Chronic Exposure Mortality	Count Valuation	-312 (-584, -44) -$1,455,270,331 (-$5,706,124,288, $1,622,349,824)
Cardiac Hospital Admissions + Respiratory Hospital Admissions	Count Valuation	-293 (-630, 43) -$1,285,828 (-$2,997,135, $273,121)
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	Count Valuation	-1,397 (-3,124, 153) -$549,901 (-$1,309,949, $59,708)
All Endpoints	Count Valuation	Not applicable -$1,366,045,919 (-$5,622,451,200, $1,765,228,032)

Note: A negative value represents a negative effect to the society and should therefore be considered as an increase in cost or health impacts. A positive value represents a positive effect to the society and should therefore be considered as a reduction in cost or health impacts.

Table 4.9 O_3: AQBAT estimates from absence of air pollutants to baseline, CC4 and CC4b scenarios

	Baseline*	CC4*	CC4b*	Baseline to CC4 (% change)	Baseline to CC4b (% change)
Acute Exposure Mortality	-3,449	-3,616	-4,158	4.84	20.56
Acute Respiratory Symptom Days	-14,381,861	-15,019,056	-17,186,586	4.43	19.50
Asthma Symptom Days	-2,041,466	-2,143,840	-2,481,305	5.01	21.55
Minor Restricted Activity Days	-4,720,256	-4,971,734	-5,818,014	5.33	23.26
Respiratory Emergency Room Visits	-8,046	-8,441	-9,691	4.91	20.44
Acute Exposure Mortality + Chronic Exposure Mortality	-3,449	-3,616	-4,158	4.84	20.56
Cardiac Hospital Admissions + Respiratory Hospital Admissions	-1,973	-2,070	-2,376	4.92	20.43
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	-8,046	-8,441	-9,691	4.91	20.44

* Only average values are presented for simplicity.

Table 4.10 PM$_{2.5}$: AQBAT estimates from absence of air pollutants to baseline, CC4 and CC4b scenarios

	Baseline*	CC4*	CC4b*	Baseline to CC4 (% change)	Baseline to CC4b (% change)
Acute Respiratory Symptom Days	-6,320,702	-5,343,659	-5,533,850	-15.46	-12.45
Adult Chronic Bronchitis Cases	-4,002	-3,321	-3,456	-17.02	-13.64
Asthma Symptom Days	-263,555	-221,890	-230,118	-15.81	-12.69
Cardiac Emergency Room Visits	-160	-135	-141	-15.63	-11.88
Cardiac Hospital Admissions	-441	-373	-386	-15.42	-12.47
Child Acute Bronchitis Episodes	-35,429	-28,669	-30,000	-19.08	-15.32
Chronic Exposure Mortality	-2,916	-2,451	-2,541	-15.95	-12.86
Respiratory Emergency Room Visits	-1,146	-970	-1,005	-15.36	-12.30
Restricted Activity Days	-4,102,799	-3,444,088	-3,574,568	-16.06	-12.87
Acute Exposure Mortality + Chronic Exposure Mortality	-2,916	-2,451	-2,541	-15.95	-12.86
Cardiac Hospital Admissions + Respiratory Hospital Admissions	-724	-613	-634	-15.33	-12.43
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	-1,306	-1,105	-1,145	-15.39	-12.33

* Only average values are presented for simplicity.

Table 4.11 Both pollutants: AQBAT estimates from absence of air pollutants to baseline, CC4 and CC4b scenarios

	Baseline*	CC4*	CC4b*	Baseline to CC4 (% change)	Baseline to CC4b (% change)
Acute Exposure Mortality	-3,449	-3,616	-4,158	4.84	20.56
Acute Respiratory Symptom Days	-20,702,562	-20,362,715	-22,720,437	-1.64	9.75
Adult Chronic Bronchitis Cases	-4,002	-3,321	-3,456	-17.02	-13.64
Asthma Symptom Days	-2,305,021	-2,365,730	-2,711,422	2.63	17.63
Cardiac Emergency Room Visits	-160	-135	-141	-15.63	-11.88
Cardiac Hospital Admissions	-441	-373	-386	-15.42	-12.47
Child Acute Bronchitis Episodes	-35,429	-28,669	-30,000	-19.08	-15.32
Chronic Exposure Mortality	-2,916	-2,451	-2,541	-15.95	-12.86
Minor Restricted Activity Days	-4,720,256	-4,971,734	-5,818,014	5.33	23.26
Respiratory Emergency Room Visits	-9,192	-9,410	-10,696	2.37	16.36

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	Baseline*	CC4*	CC4b*	Baseline to CC4 (% change)	Baseline to CC4b (% change)
Restricted Activity Days	-4,102,799	-3,444,088	-3,574,568	-16.06	-12.87
Acute Exposure Mortality + Chronic Exposure Mortality	-6,366	-6,068	-6,699	-4.68	5.23
Cardiac Hospital Admissions + Respiratory Hospital Admissions	-2,697	-2,682	-3,010	-0.56	11.61
Cardiac Emergency Room Visits + Respiratory Emergency Room Visits	-9,353	-9,546	-10,836	2.06	15.86

* Only average values are presented for simplicity.

Table 4.12 AQBAT valuation information

Endpoint	Sources of derivation	Form	Parameter 1	Parameter 2	Parameter 3
Acute Exposure Mortality	Jones-Lee et al., 1985; Cropper and Freeman, 1991; Rowe et al., 1995	Discrete	Low valuation= $2,637,960 (probability=33%)	Central valuation= $4,506,516 (probability=50%)	High valuation= $9,013,031 (probability=17%)
Acute Respiratory Symptom Days	Stieb et al., 2002	Normal	Mean valuation= $14.06	SD of valuation= $10.82	
Adult Chronic Bronchitis Cases	Viscusi et al., 1991; Krupnick and Cropper, 1992	Discrete	Low valuation= $192,351 (probability=33%)	Central valuation= $292,374 (probability=34%)	High valuation= $511,105 (probability=33%)
Asthma Symptom Days	Stieb et al., 2002	Triangular	Minimum valuation=$7.57	Most likely valuation=$30.29	Maximum valuation=$129.81
Cardiac Emergency Room Visits	Stieb et al., 2002	Normal	Mean valuation= $393.85	SD of valuation= $65.64	
Cardiac Hospital Admissions	Stieb et al., 2002	Normal	Mean valuation= $5,689	SD of valuation= $984.64	
Child Acute Bronchitis Episodes	Krupnick and Cropper, 1989	Discrete	Low valuation= $166.43 (probability=33%)	Central valuation= $343.96 (probability=34%)	High valuation= $510.39 (probability=33%)
Chronic Exposure Mortality	Jones-Lee et al., 1985; Cropper and Freeman, 1991; Rowe et al., 1995	Discrete	Low valuation= $2,637,960 (probability=33%)	Central valuation= $4,506,516 (probability=50%)	High valuation= $9,013,031 (probability=17%)
Minor Restricted Activity Days	Stieb et al., 2002	Discrete	Low valuation= $21.64 (probability=33%)	Central valuation= $35.70 (probability=34%)	High valuation= $61.66 (probability=33%)
Respiratory Emergency Room Visits	Stieb et al., 2002	Normal	Mean valuation= $393.85	SD of valuation= $65.64	
Respiratory Hospital Admissions	Stieb et al., 2002	Normal	Mean valuation= $4,595	SD of valuation= $656.42	
Restricted Activity Days	Stieb et al., 2002	Normal	Mean valuation= $51.93	SD of valuation= $27.04	

Note: SD, standard deviation.

Table 4.13 AQBAT concentration response function

Source for derivation of CRF	Pollutant	Averaging period	Health endpoint	Specified population	Regression type	Baseline rate (events per quarter per million specified population)	Excess for a unit concentration increase	
							Mean	Standard error
Internal AHED sub-analysis based on R. Burnett's 1981–2000 data and methods	O_3	1 hour	Acute Exposure Mortality	Total population	Poisson	CD specific	0.127%	0.0212%
Krupnick, 1990	O_3	1 hour	Acute Respiratory Symptom Days	94% (non-asthmatics) of the total population	Linear	16,000,000	0.0786%	0.0386%
Stock et al., 1988; Whittemore and Korn, 1980	O_3	1 hour	Asthma Symptom Days	6% (asthmatics) of the total population	Logistic	12,000,000	0.173%	0.0552%
Ostro and Rothschild, 1989	O_3	1 hour	Minor Restricted Activity Days	94% (non-asthmatics) of the total population	Poisson	2,000,000	0.0530%	0.291%
Burnett et al., 1997; Stieb et al., 2000	O_3	1 hour	Respiratory Emergency Room Visits	Total population	Poisson	CD specific	0.0791%	0.0355%
Burnett et al., 1997	O_3	1 hour	Respiratory Hospital Admissions	Total population	Poisson	CD specific	0.0791%	0.0355%
Krupnick, 1990	$PM_{2.5}$	24 hours	Acute Respiratory Symptom Days	94% (non-asthmatics) of the total population	Linear	16,000,000	0.266%	0.139%
Abbey et al., 1995	$PM_{2.5}$	24 hours	Adult Chronic Bronchitis Cases	Population 25 years old and over	Logistic	1,600	1.33%	0.689%
Whittemore and Korn, 1980	$PM_{2.5}$	24 hours	Asthma Symptom Days	6% (asthmatics) of the total population	Logistic	12,000,000	0.144%	0.0559%
Burnett et al., 1995; Stieb et al., 2000	$PM_{2.5}$	24 hours	Cardiac Emergency Room Visits	Total population	Linear	CD specific	0.0711%	0.0170%
Burnett et al., 1995	$PM_{2.5}$	24 hours	Cardiac Hospital Admissions	Total population	Linear	CD specific	0.0711%	0.0170%
Dockery et al., 1996	$PM_{2.5}$	24 hours	Child Acute Bronchitis Episodes	Population under 20 years old	Logistic	16,000	2.76%	1.73%
Krewski et al., 2000	$PM_{2.5}$	24 hours	Chronic Exposure Mortality	Total population	Poisson	CD specific	0.678%	0.164%

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Source for derivation of CRF	Pollutant	Averaging period	Health endpoint	Specified population	Regression type	Baseline rate (events per quarter per million specified population)	Excess for a unit concentration increase	
							Mean	Standard error
Burnett et al., 1995	$PM_{2.5}$	24 hours	Respiratory Emergency Room Visits	Total population	Linear	CD specific	0.0754%	0.0132%
Burnett et al., 1995	$PM_{2.5}$	24 hours	Respiratory Hospital Admissions	Total population	Linear	CD specific	0.0754%	0.0132%
Ostro, 1987	$PM_{2.5}$	24 hours	Restricted Activity Days	94% (non-asthmatics) of the population 20 years old and over	Poisson	4,700,000	0.482%	0.101%

Note: CD, census division

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Chapter 5

The Impacts of Climate Change on Water-, Food-, Vector- and Rodent-Borne Diseases


Dominique Charron
Manon Fleury
L. Robbin Lindsay
Nicholas Ogden
Corinne J. Schuster

Contributor:
David Noble

Chapter 5

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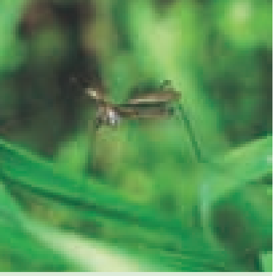


Chapter 5

5.1 INTRODUCTION

This chapter examines the potential effects of climate change on the risk in Canada from food-, water-, vector- and rodent-borne diseases, many of which are zoonoses. It concludes with a discussion of the future actions required to minimize the impact of these diseases on human health. Characterizing changes in disease patterns in Canada resulting from climate change is fundamental to reducing any potential additional burden of illness. There has been a resurgence of infectious diseases in many parts of the world, and the incidence of food- and water-related contamination is also increasing (Becker et al., 2006). This situation reflects an unprecedented convergence of a number of diverse and globally important factors that include climate change, as well as population growth, density of settlement, travel, trade, agricultural intensification, urbanization and the overuse of antibacterial agents and pesticides.

Vector-borne and zoonotic diseases

Diseases that must be transmitted by an invertebrate host (such as a mosquito or tick) are termed vector-borne diseases. Zoonoses are infections that occur in animals that can also infect humans. All rodent-borne and many food-, water- and vector-borne infections are zoonotic.

Climate variability influences risks and patterns of disease and health. Many infectious diseases occur seasonally. For example, food- and vector-borne illnesses peak during warmer months in temperate climates like Canada's, whereas influenza and gastroenteric viruses predominate in winter (Grassley and Fraser, 2006). The effects of weather and climate on the majority of food-, water-, vector- and rodent-borne diseases are mediated through influences on pathogens, their transportation routes, their invertebrate vectors, their animal hosts, or on human behaviour. Furthermore, people perform different activities at different times of the year, thus resulting in "seasonality" in their risk of injury, infection or illness, depending on the activity. Therefore, relationships between climate and illness arising from food-, water-, vector- and rodent-borne sources are more complex than the direct effects of climate and weather on, for example, mortality from extreme heat or cold, or injuries from extreme weather.

Climate change is very likely to affect the normal patterns of disease across the country, and may result in the emergence of diseases that are currently thought rare or exotic to Canada. The increased average temperatures projected as a result of climate change could increase the survival or replication rates of vectors and some food- and water-borne pathogens, but could hamper the survival of others. Longer and warmer summers could increase pathogen survival in certain types of food, or in food improperly prepared or stored during summer months. More frequent and intense rainfall events may increase

water contamination and lead to water-borne disease outbreaks. Milder winters followed by hotter and more humid summers could favour West Nile virus and Lyme disease, but drought or heavy rainfall may keep them in control.

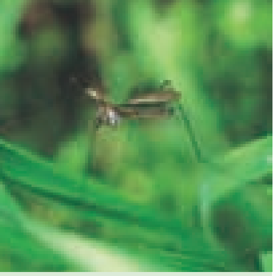
Changes in the expected seasonal and geographic patterns of food-, water-, vector-borne and zoonotic infections have implications for public health. Many of these infections can be prevented through targeted health promotion messages that encourage people to modify their behaviour to reduce their risk. Because foreknowledge of increased risk in certain areas or at certain times may heighten clinical recognition and diagnosis, health practitioners need to know when and what to expect. For example, some early symptoms of Lyme disease have a high diagnostic value (that is, they allow effective treatment if detected early), and practitioner awareness of these symptoms will allow early detection and treatment, which is key to reducing the impact of this disease. There is, however, much experience in managing disease risks in Canada to protect public health. Considerable effort is expended in ensuring that foods are free from contamination from farm-to-fork, and that drinking water is free from contamination with infective or other agents that are harmful to health. Thus, while effects of climate change may result in some completely new or increased health risks, existing infrastructure could protect against some risks being realized as public health problems.

5.1.1 Method and Approach

This chapter is based on a review of key Canadian and international scientific literature, Internet sites and reports of Canadian and international public health organizations. For many reasons, including the uncertainties associated with climate change projections themselves, most current literature can suggest only possible futures under given climate change scenarios, based on global climate model simulations. As such, this chapter reviews possible effects of climate change based on changes to climate expected for Canada, according to the Intergovernmental Panel on Climate Change (IPCC, 2007a, 2007b), with the understanding that actual future conditions could be different. In particular, it should be recognized that the potential impacts of climate change on disease in Canada are at early stages of investigation, and that this review may not represent the complete range of potential risks.

The review covers current knowledge of the effects of climate and climate change on risks of diseases that are endemic to Canada, where these data exist. Where they do not, the review considers potential effects of climate and climate change on disease risks using current understanding of these relationships (actual or potential) based on studies elsewhere in the world. The potential for exotic diseases (i.e. those not currently present in Canada) to become established here as a consequence of climate change is also reviewed although, where possible, geographically close risks are differentiated from those that are much more distant.

The review scans across a wide range of disease risks from food-, water-, vector- and rodent-borne sources that may increase, decrease or emerge as a consequence of climate change. Prioritization of particular risks for action in terms of adaptation efforts will require a more systematic risk assessment; the conclusions section (5.5) provides suggestions for the adaptation process, from risk assessment to surveillance and intervention. Until a more systematic risk assessment and prioritization is complete, the precautionary principle can be used to minimize impacts and provide general protection against emerging disease risks (Soskolne, 2004).



5.2 FOOD- AND WATER-BORNE DISEASES

5.2.1 Food-Borne Diseases

Food-borne illnesses are defined as diseases that are infectious, parasitic or toxic in nature, and that are acquired through the ingestion of contaminated food. The symptoms resulting from food-borne pathogens vary from gastrointestinal (nausea, vomiting, diarrhoea and abdominal pain) to neurological (e.g. Guillain-Barré syndrome, which can be caused by *Campylobacter* infection), acute kidney failure and hemolytic uremic syndrome caused by infection with *Escherichia coli* O157:H7, and congenital malformations due to *Toxoplasma gondii* infection (Centers for Disease Control (CDC), 2005b). The most common food-borne pathogens in Canada are *Salmonella, Campylobacter* and *E. coli* (Public Health Agency of Canada (PHAC), 2003).

Canadians rely on safe food. Many systems exist to ensure food safety, from the farm through harvest and processing, to retail and consumption. Along the food production chain, there are links where these systems may be vulnerable to climatic influences. For example:

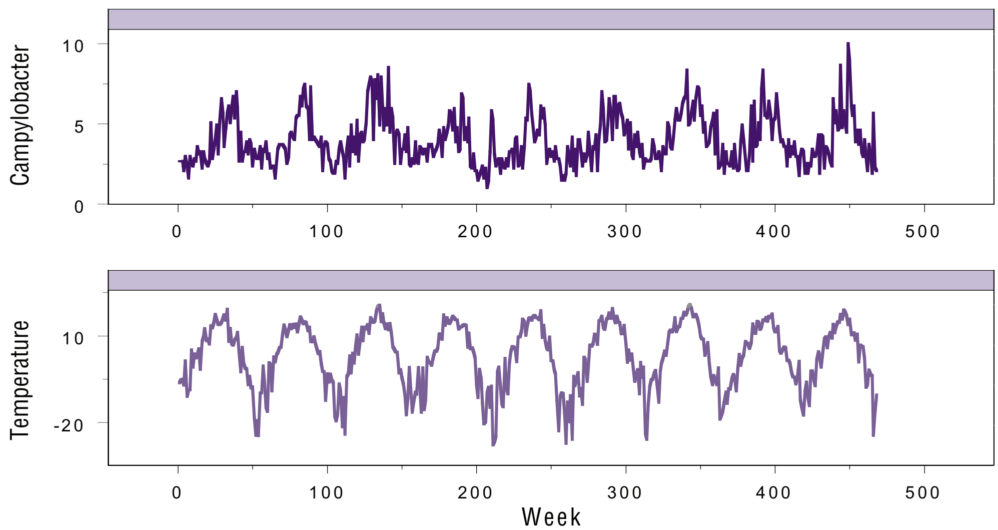
- Livestock stressed by temperature or other factors on-farm or during transport may be more likely to become ill or to shed greater amounts of harmful bacteria and viruses (Keen et al., 2003). Increased local risk of contamination would ensue, along with the potential for enhanced survival or even replication of pathogens, leading to a greater risk of meat contamination during processing. Ill livestock may require antimicrobials, contributing to the development of antimicrobial resistance; this could make both animal and human infections more difficult to treat (Nicholls et al., 2001; Danish Integrated Antimicrobial resistance Monitoring and Research Programme, 2002; World Health Organization, 2002).
- Agriculture may be affected by climate change (McGinn et al., 1999). Environmental changes as a result of increased drought, crop failure as a result of drought or ill-timed heavy rainfall, and loss of soil fertility can result in decreased yields or total loss of production.
- Climate-related changes in wild bird and wild animal population health may bring about new bio-security issues for Canadian farmers, potentially leading to the emergence of new food-borne pathogens.
- Heat waves and power outages related to high-energy demands or to extreme weather could cause refrigeration failure during food processing and storage, compromising food safety.

Food-borne infections may be linked to foods originating from infected animals, or from food that has been contaminated by fecal matter directly from an animal or person, or indirectly via contaminated water (Rose and Slifko, 1992; Chin, 2000; Rose et al., 2001; Hall et al., 2002). Reports of food-borne illness peak in the summer in Canada (Isaacs et al., 1998). Figure 5.1 shows the relationship between weekly case counts of *Campylobacter* and average weekly air temperature. The survival rates of most enteric pathogens in the

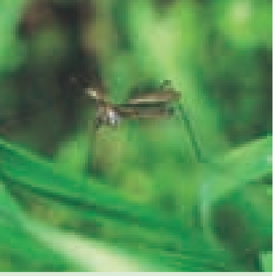
environment are, within limits, positively correlated with ambient temperature (Hall et al., 2002). Indeed, many food-borne diseases show a strong seasonal pattern in most temperate developed countries. Some of the increase is likely attributable to changes in certain social behaviours associated with a higher risk of food-borne illness (e.g. barbeques, picnics, camping) and to increased risk of food spoilage. However, some of this seasonal increase is more directly associated with increased temperature. A recent study in Canada found a link between ambient temperature and the occurrence of *Salmonella, Campylobacter* and *E. coli* O157 infections, above and beyond any seasonal trend. It was found that the relative risk of disease increased by 1.2 to 6.0% per degree Celsius above a statistical temperature threshold level (Fleury et al., 2006). These findings were consistent with studies conducted in Australia and the U.K. (Bentham and Langford, 1995, 2001; D'Souza et al., 2004; Kovats et al., 2004a, 2004b).

Climate change could affect the risks of food-borne diseases in two ways. Longer summers will extend the period associated with higher risk behaviours, and hotter temperatures exceeding a certain threshold will contribute to higher incidence of disease. As a result, the summer food-borne disease incidence peak could include a greater number of cases over a longer period. With increased temperatures due to climate change, home and restaurant food preparation practices would likely need to change to adapt to the increased risk of spoilage and contamination during warmer months.

Figure 5.1 Seasonal pattern of mean temperature and weekly case counts of *Campylobacter* in Alberta by week from the first week of January 1992 to the last week of December 2000



The Canadian Arctic has already demonstrated ecological change as a result of a changing climate. Seasonal shifts involving earlier spring onset and later ice formation and overall warmer temperatures have implications for traditional lifestyles, wild food availability, and food preparation and storage. Some animal populations upon which Aboriginal people depend may disappear entirely because of habitat loss attributable to climate change (Weller and Lange, 1999; Nuttall et al., 2005). Traditional food preparation and storage that rely on refrigeration in permafrost may no longer be possible. Higher ambient temperatures in the Arctic may result in an increase in some temperature-sensitive food-borne diseases, such as gastroenteritis, paralytic shellfish poisoning and botulism (Parkinson and Butler, 2005). Outbreaks of botulism poisoning in northern Canada have been linked to modifications of



traditional food practices or practices implemented in inappropriate climates (Proulx et al., 1997; Horn et al., 2001). Furthermore, there may be an increase in the range and type of animal hosts of diseases transmissible to humans, including hydatid disease caused by the larvae of tapeworms that usually live in wild and domestic ruminants and canids. The larvae may cause dangerous infections in people in northern Canada who hunt game and keep dogs (Rausch, 2003; Parkinson and Butler, 2005).

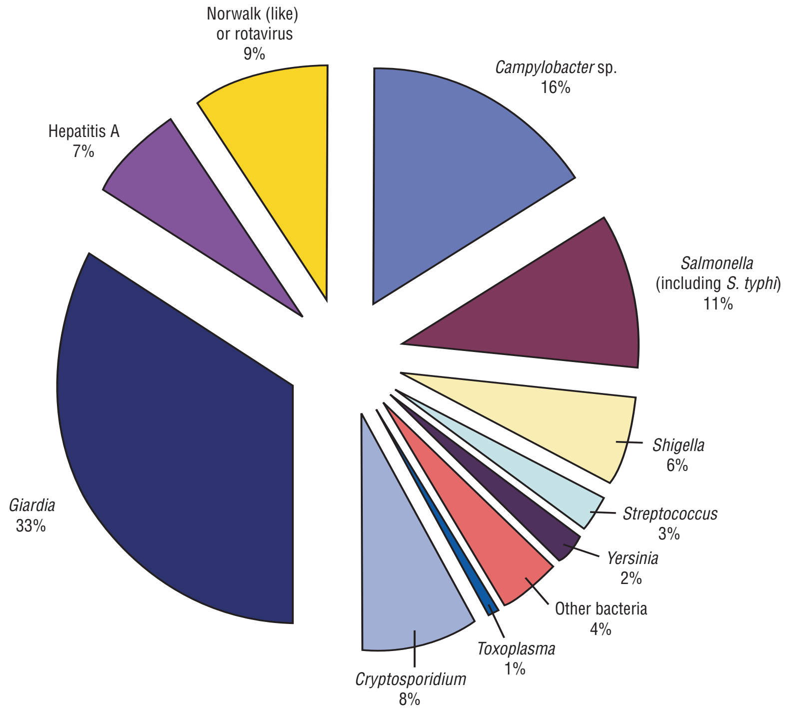
Other risks to Canadians living in coastal areas are microalgae that form the basis of the marine food chain, and toxin-producing species that may seriously disrupt the food web and lead to fish kills and human toxicity through the ingestion of contaminated fish (CDC, 2005d; Peperzak, 2005). The Canadian Food Inspection Agency (CFIA) monitors shellfish for the toxins that cause several types of poisoning with neurological or gastrointestinal symptoms (CFIA, 2003). Toxic freshwater and marine algae associated with eutrophication (the nutrient enrichment of a body of water which leads to more productivity), are present in Canadian waters and can become a danger to public health during the warm season (McCarthy et al., 2001; Weise et al., 2001). Warmer temperatures will affect the geographic range and the magnitude of certain algal blooms, and may induce oceanic changes that favour potentially harmful species (Zingone and Enevoldsen, 2000).

5.2.2 Water-Borne Illnesses

Water-borne illnesses result from exposure to pathogenic microorganisms or chemicals in drinking water or recreational water. Contaminated water most often enters the body by ingestion, but contaminants in water can also be inhaled or adsorbed, or enter the body through contact with open sores or wounds. The majority of symptoms resulting from water-borne pathogens are enteric (nausea, vomiting and diarrhoea and, in rare circumstances, colitis). However, other symptoms can be neurological, cardiovascular, respiratory (*Legionella*), ocular (toxoplasmosis), haematological (septicaemia from *E. coli* O157:H7) or dermatological (Payment and Pintar, 2006). Not only do exposure sources vary, but so do exposure lengths, dose-responses, incubation times and illness onset times, depending on the type of contamination (both general and specific). For example, microbiological contamination generally has a small exposure time, faster onset of illness and a lower dose-response than chemical or radiological contamination.

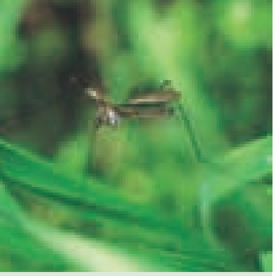
Gastroenteric pathogens, such as *Giardia, Cryptosporidium, Campylobacter, Shigella* and verotoxigenic *E. coli* are by far the most common endemic water-borne disease hazards in Canada and are reported to the National Notifiable Disease Registry database (Charron et al., 2004). In Canada, water-borne disease outbreaks have been associated with *E. coli* O157:H7, *Campylobacter,* occasionally *Shigella* and other pathogens (Levy et al., 1998; Lee et al., 2002; Oliver et al., 2003; Charron et al., 2004; Schuster et al., 2005) (Figure 5.2). Cholera has been reported in Canada and other pathogens such as hepatitis A, leptospirosis and Legionnaire's disease can also be considered as water-borne illnesses (Health Canada, 2002; Charron et al., 2004). Water-borne pathogens have a combination of human, wild and domesticated animal reservoirs and are released into the environment through waste products that can be deposited directly on the ground, spread as a result of agricultural activity or leach from septic systems or sewage pipes. Contamination of water with these pathogens can occur in several ways, but the most common is from overland flow (or storm water runoff in urban environments) that flushes contaminants into streams, rivers and lakes and that can transport contaminants into groundwater under certain environmental conditions. Weather has been linked to a number of reported water-borne disease outbreaks in Canada (Hrudey et al., 2003; Schuster et al., 2005). Sea water can also be a source of infection, as demonstrated in the food-borne diseases section (5.2.1). In 1997, *Vibrio parahaemolyticus,* a gastrointestinal pathogen that can also cause infection of open wounds, was associated with an outbreak from raw and undercooked oysters in British Columbia (Fyfe et al., 1997). It has also been associated with wound infections as a result of swimming in the ocean off the west coast of Canada (Todd, 1997).

Figure 5.2 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)*



Interventions are primarily geared to immediate, acute public health risks that occur through exposure to microbiological contaminants. Risks of illness from water-borne chemical contaminants have been extensively investigated in Canada, particularly nitrates in groundwater (Arbuckle et al., 1988; Levallois et al., 1998, 2000; VanLeeuwen et al., 1999; Thompson, 2001), metals (Bernier et al., 1995; Mao et al., 1995; Baldwin et al., 1999; Eisler, 2004), persistent organic pollutants (Chiu et al., 2004) and pharmaceuticals (Ternes et al., 1999; Metcalfe et al., 2003). Water-borne radiological contamination can also occur, generally a result of natural background radiation. Drinking water guidelines reflect the fact that the contribution of radiation and chemical contamination from drinking water is a very small fraction of total exposure (Health Canada, 2004). To date no illnesses have been attributed to chemical contaminants in drinking water in Canada. Research is ongoing to further examine the potential health effects of chemical contaminants and to assess the effectiveness of current drinking water and wastewater treatment technologies. Findings continually inform the development of Water Quality Guidelines in Canada led by the Federal-Provincial-Territorial Committee on Drinking Water, and support the management of water quality in Canada.

Increased temperatures and greater variation in precipitation with climate change are likely to alter the risk of enteric water-borne disease through a number of mechanisms. Increases in precipitation intensity and frequency are likely to enhance overland flow or flooding and increase erosion, with the potential for surface and groundwater contamination by enteric pathogens and decreased effectiveness of water treatment. Previous water-borne outbreaks in Canada have been associated with heavy precipitation, spring melt, snowmelt and flooding (Bowie et al., 1997; Charron et al., 2004; Schuster et al., 2005; Thomas et al., 2006). In May 2001, excess rainfall resulted in contamination of groundwater and contributed to the Walkerton outbreak of *E. coli* O157:H7 in which 2,300 people became sick and seven people died (Auld et al., 2004). Curriero et al. (2001) quantified links between precipitation and water-borne disease outbreaks (enteric) in the U.S. The findings demonstrated that 51% of the 548 reported outbreaks



were preceded by monthly accumulated precipitation events greater than the 90th percentile (P=0.002) and that 68% were preceded by events greater than the 80th percentile (P=0.001). A study in Canada by Thomas et al. (2006) demonstrated that accumulated rainfall totals over the six weeks prior to an outbreak greater than the 93rd percentile doubled the risk of an outbreak. Heavy rainfall resulting in flooding can cause chemical contamination. Threats of chemical contamination after flooding have been reported, but the resulting health impacts are less well described (Wing et al., 2002; Euripidou and Murray, 2004).

Drought increases the demand for water when the supply is significantly reduced and vulnerable. It concentrates pathogens and chemical and radiological contaminants in water, and has implications for hygiene practices in light of water use restrictions. Furthermore, heavy rain following drought can lead to overland flow events and increased risk of water contamination (Charron et al., 2004). Increased ambient temperatures are likely to be associated with increased survival and abundance of microorganisms, and thus an enhanced water-borne infection risk. Thomas et al. (2006) found that for every 1°C increase in the six-week maximum positive degree-days total increased the relative odds of a water-borne disease outbreak by 1.007 times. Although this odds ratio is small per degree day, the practical implications are important; for example, a 5°C increase in maximum daily temperature over a 42-day period would result in a more than four-fold increase in risk.

Changes in contaminant transport are already being noted as a result of climate change, particularly in the Arctic due to permafrost thaw (Macdonald et al., 2005). Martin et al. (2005) found that 30% of the Inuit population in Nunavik depend on untreated water for consumption, such as rivers and lakes in the summer and melting snow or ice in the winter and spring. There is an increased risk of water-borne diseases to this population given climate warming, and increased rates of illness are already being seen compared to the rest of Quebec. There are additional concerns that shoreline erosion and flooding as a result of sea level rise could lead to contamination of aquifers with leakage from subterranean chemical dumps. The rise in sea level may displace Canadians in coastal communities, resulting in temporary disruptions in water supply. Further, saltwater intrusion can result in a need for alternate fresh water sources.

There is evidence that climate variables influence the risk of water-borne disease pathogens in Canada. How climate change will change conditions to favour the introduction of new disease to Canada or the re-establishment of diseases that have been eradicated is also of concern. Two emerging or potential water-borne diseases of concern for Canada are leptospirosis and cholera. Peak occurrences of leptospirosis in animals have been associated with high precipitation levels and warm, wet late-summer and autumn conditions in eastern Canada (Vinetz et al., 1996). In Canada, it is recognized as an uncommon disease but one that may be underestimated (Levesque et al., 1995). Warmer winters and increased temperature are likely to allow leptospires to survive longer in standing water in many parts of Canada, possibly contributing to increased risk of exposure through bathing or swimming (Jansen et al., 2005). It is among a few diseases at risk of a global resurgence under conditions of climate change (Epstein et al., 1995; Koelle et al., 2005) with implications for Canadians at home and abroad. Cholera, or acute enteritis caused by the bacterium *Vibrio cholerae,* is another example. It is extremely rare and not endemic to Canada, although it does occur in Canadians who have travelled abroad to areas where the disease is endemic (PHAC, 2007a). Cholera was common in Canada up to the late 19th century, but the likelihood of it becoming endemic again is minimal because of modern sanitation and public health practices, even though the causative organism is present along the east and gulf coasts of the U.S. in and on blue-green algae and copepods (“water fleas”) and perhaps also in shellfish (Huq et al., 2001). A warming of the Canadian coastal waters in the Maritimes and Quebec might therefore enable a northward spread of *V. cholerae.*

Chapter 5

5.3 VECTOR- AND RODENT-BORNE DISEASES

In 2001, Kovats et al. (2001) concluded that the literature to date contained no strong evidence that the change in climate observed in the previous few decades had affected vector-borne diseases. At that time, concerns that climate change could alter the risk from vector-borne disease rested on scarce and often speculative evidence (Githeko et al., 2000). However, more recent studies provide more certainty that climate change is already affecting some vector-borne disease risks, and that changing patterns could further affect human health in the future (McMichael et al., 2004; Purse et al., 2005).

5.3.1 West Nile Virus and Other Mosquito-Borne Diseases

In North America, mosquitoes and some ticks carry several zoonotic viral pathogens that can cause disease in humans. These viruses include West Nile virus, St. Louis encephalitis, western equine encephalitis and eastern equine encephalitis viruses. Most people infected with these pathogens may not show symptoms, although of the ones who do, the symptoms are often similar and start as mild flu-like symptoms, occasionally progressing to severe encephalitis (inflammation of the brain), at times resulting in death (Pepperell et al., 2003).

Arthropods and arboviruses

Arthropods are members of the phylum Arthropoda, which includes such familiar forms as spiders, insects, centipedes and millipedes as well as disease vectors such as mosquitoes and ticks. Arboviruses (a contraction of "arthropod-borne viruses") are viruses that can develop within, and be transmitted by, arthropods.

West Nile virus is a mosquito-borne illness brought to Canada by migratory birds in 2001 (Pepperell et al., 2003), which has spread across Canada, with the exception of British Columbia, Newfoundland and Labrador, Yukon, Nunavut and the Northwest Territories. Over 1,800 human cases have been reported in Canada from 2002 to 2005, with 46 of these resulting in death. The long-term effects of West Nile virus are not fully understood; some people with serious symptoms recover fully whereas others experience prolonged neurological health problems (PHAC, 2006). Cases have been concentrated in a number of urban and semi-urban areas of southern Quebec and southern Ontario, and in rural populations in the Prairies (Pepperell et al., 2003; Gaulin et al., 2004; Manitoba Health, 2007). The outbreaks correlate with the presence and abundance of the mosquito species primarily responsible for West Nile virus spread and transmission to people.

The ecology, development, behaviour and survival of arthropod vectors, and the transmission dynamics of arboviruses are strongly influenced by climatic factors (Reiter, 2001). Temperature determines the speed and success of the arthropod life cycle and adult survival, and determines whether viruses replicate and spread from the mosquito gut to the salivary glands fast enough for the vector to transmit infection before it dies—the "extrinsic incubation period" (Randolph, 1998). Many arboviruses cause diseases in animals and can infect humans. The viruses are transmitted to humans by "bridge" vectors, species that feed on both animal hosts and humans (CDC, 2003; Turell et al., 2003).

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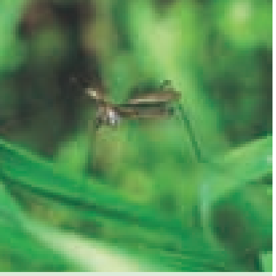


Canada lies at what is currently the northern margin for efficient transmission of most arboviruses, so disease outbreaks tend to be rare and have historically tended to occur in late summer.

The life cycles of mosquito and pathogen transmission are temperature dependent. Higher summer temperatures would speed up the life cycles of mosquitoes, which might lengthen the overall transmission season (Patz and Reisen, 2001) and could expand the geographic range of mosquito vectors. All of these conditions would increase the likelihood of virus amplification and transmission to humans. Specifically, warm winters and heat waves may favour West Nile virus, while in some parts of the world droughts may enhance transmission (Epstein, 2001a). Mild winters favour the overwintering survival of female *Culex* mosquitoes, and drought conditions may also force birds to congregate around shrinking water bodies, thus potentially enhancing local cycles of virus amplification (Epstein, 2001b; Epstein and Defilippo, 2001).

Like West Nile virus, St. Louis encephalitis virus cycles between wild birds and mosquitoes (*Culex* spp.) that prefer birds, and is occasionally transmitted to humans by infected mosquitoes. There are usually fewer than 50 cases of St. Louis encephalitis virus infection reported per year in the U.S.; however, periodically, large epidemics involving hundreds of infected individuals occur, primarily in the midwest and southeast states (CDC, 2006a). The only major outbreak of St. Louis encephalitis in Canada occurred in 1975 and 1976 in southern Ontario, apparently an extension of the outbreak that occurred in the midwestern U.S. (Spence et al., 1977). Outbreaks of St. Louis encephalitis have occurred in the U.S. as recently as 2001 (Jones et al., 2002).

Climate change is expected to alter the distribution of St. Louis encephalitis in North America, possibly ceasing its endemic cycle in the southwestern U.S. due to unfavourably warm temperatures projected for this area. A northward expansion of the virus into Canada is possible (Reeves et al., 1994).

Both western equine encephalitis and eastern equine encephalitis viruses can cause illness in humans. Sporadic equine epizootics (disease outbreaks among animal populations) of eastern equine encephalitis occur in Ontario and Quebec, while western equine encephalitis has been reported across Canada from Lake Superior to the Rocky Mountains and in British Columbia (Artsob, 1986; Keane and Little, 1987; Carman et al., 1995; Duncan et al., 1998; Leighton, 2000). Outbreaks of western equine encephalitis (typically involving horses) have occurred in Canada in each decade since 1930. Human infections of western equine encephalitis are now fortunately rare and only occasionally result in severe illness. Sporadic cases are reported, more often in early June or July (Leighton, 2000). In contrast, eastern equine encephalitis virus infections can cause severe illness in people, with a case fatality rate near 33% and possible long-term debilitating sequelae in many survivors (Leighton, 2000; CDC, 2005c). Indigenous cases of eastern equine encephalitis infection in humans have not been observed in Canada.

In most years, western equine encephalitis transmission occurs at a low level in the rural West. The virus' maintenance cycle principally involves birds and *Cx. tarsalis* and human and equine infections that occur outside the maintenance cycle, resulting in small numbers of sporadically occurring cases (Hayes, 1981; Tsai and Monath, 1987). However, at intervals of 5 to 10 years and for reasons poorly understood, viral transmission in the maintenance cycle is more intense, and humans and equines become infected at epidemic and epizootic levels. Outbreaks have often affected wide areas of the western U.S. and Canada. In 1941, more than 3,400 cases among humans occurred in Canada with an attack rate of 167 per 100,000,

affecting populations in the northern plains states and in the provinces of Manitoba, Alberta and Saskatchewan (Leake, 1941). The most recent outbreak was in 1975 in the Red River Valley with 277 reported cases among humans and 281 among equines (Potter et al., 1977; Leech et al., 1981).

The principal vectors for western equine encephalitis and eastern equine encephalitis viruses are endemic in some parts of Canada. Current temperature conditions in Canada may be generally too cold for replication of eastern equine encephalitis viruses in these vectors such that transmission cycles can persist (Reeves et al., 1994), but to what extent eastern equine encephalitis is endemic to Canada (as opposed to only intermittently expanding its ranges into the country) is unclear. Increased temperatures with climate change may favour local amplification of the viruses, as is predicted for other arboviruses (Patz et al., 1998). Outbreaks of eastern equine encephalitis have been associated with warm, wet summers along the east coast of the U.S. (Freier, 1993). Heavy rainfall may increase vector abundance and precipitate mosquito-borne disease epidemics; indeed, the Red River Valley western equine encephalitis outbreak of 1975 followed severe flooding (Nasci and Moore, 1998).

It is likely that public health systems in Canada are not yet prepared to respond specifically to any health risks from St. Louis encephalitis, or western and eastern equine encephalitides. Because they are rare in Canada, they are currently unlikely to be considered as differential diagnoses. However, serological diagnosis of clinical encephalitis cases in humans in Canada, for which West Nile virus is a suspected cause, is mostly performed at the National Microbiology Laboratory, Winnipeg, where samples are routinely tested for St. Louis encephalitis, western equine encephalitis and eastern equine encephalitis as well as for West Nile virus. Therefore, the presence of these viruses in Canada would be expected to be alerted by the occurrence of human cases. However, control of West Nile virus rests on surveillance for infection in sentinel animals and vector populations, which allows control, prior to the occurrence of human cases (PHAC, 2007b). At present, there is no such surveillance for St. Louis encephalitis, western equine encephalitis and eastern equine encephalitis.

Introduction of vector-borne diseases from more distant geographic locations internationally is possible, as demonstrated by the West Nile virus epidemic in North America (see the importation of exotic diseases, section 5.3.4). Some diseases, such as West Nile virus, could become endemic if a suitable community of animal reservoirs and arthropod vectors existed in Canada. Of particular concern is the potential for vector-borne diseases of global importance, such as dengue fever and malaria, to become established in Canada as the climate warms.

Dengue fever is an arboviral infection that is endemic in most of the world. Over 2.5 billion people live in endemic regions and are at risk. The incidence of this disease is estimated at over 50 million infections per year (CDC, 2006a). The principal vector for dengue transmission to humans, *Aedes aegypti,* is exotic to Canada, but is present in the southern U.S.. Another mosquito, *Ae. albopictus,* is capable of transmitting dengue and other arboviruses to humans; it was inadvertently introduced into the southern U.S. in the early 1980s (Reiter, 1998; O'Meara et al., 1995). It has spread throughout the southeastern U.S., as far north as Wisconsin. There is speculation that climate change could facilitate further range expansion of *Ae. albopictus,* and this may have implications for Canada. There have been conflicting assessments of climate change impacts on risks from dengue and malaria, at least in part because these are mostly transmitted from human to human by mosquitoes, rather than from wildlife as is the case for West Nile virus and St. Louis encephalitis. For example, Patz et al. (1998) suggested that the risk of dengue fever was likely to increase markedly with climate change because of increased temperature suitability for transmission cycles. However, Rogers and Randolph (2000) suggested that a number of factors may limit the effects of climate change. Furthermore, Reiter (2001) concluded that it was unreasonable to use climate to predict future patterns of dengue and malaria because these are more profoundly affected by human factors that affect risk. For cases of human dengue to occur in Canada, some of the introduced *Ae. albopictus* would have to be infected with the virus and have optimal climatic conditions for transmission. At present, there is insufficient information to assess whether dengue could become established in Canada.

The World Health Organization estimates that malaria, which is caused by *Plasmodium* spp. parasites, results in more than 300 million acute cases of disease worldwide and at least one million deaths annually. Malaria was endemic to certain regions of southwestern Canada in the 17th to early 20th centuries. It is possible that persistently infected immigrant workers introduced malaria, which was then maintained by vectors endemic to Canada. Malaria has long since been eradicated (Zucker, 1996), probably due to appropriate treatment of cases, destruction of breeding sites, use of window screens and reduction in malaria levels in Europe over the 19th century (MacLean and Ward, 1999).

Global climate change is projected to alter the endemic range of both dengue and malaria (Rogers and Randolph, 2000; Sutherst, 2004), although to what extent and where range expansion will occur is very much debated (Rogers and Randolph, 2006). Climate change related alterations in the worldwide distribution and intensity of various vector-borne diseases could significantly affect the health of Canadian travellers and the demand for specialized diagnostic and treatment at home. Global increases in endemic malaria, increased resistance to anti-malarial drug therapy, and a significant increase in global travel have resulted in thousands of cases of malaria transported into Europe and North America annually, with a few giving rise to transmission by indigenous mosquitoes (Fayer, 2000). Travel between Canada and endemic regions also has potential for pathogen introduction and localized transmission in areas where competent vectors are present and climate permits. This may create new health risks for Canadian travellers abroad who may be exposed to new endemic foci.

5.3.2 Lyme Disease and Other Tick-Borne Zoonoses

Lyme disease (also called Lyme borreliosis) is a bacterial infection that causes a skin rash, chronic arthritis, nervous system disorders and debilitation. It is caused by the bacterium *Borrelia burgdorferi*. The ticks transmit infection when they attach to the skin in order to feed on blood. Lyme disease is a zoonosis; ticks transmit *B. burgdorferi* from one wild animal host (rodents are particularly important) to another but, because the ticks are unselective in their choice of hosts, they can feed on humans and infect them with the bacterium. Humans do not take part in cycles of transmission and are dead-end hosts for *B. burgdorferi.*

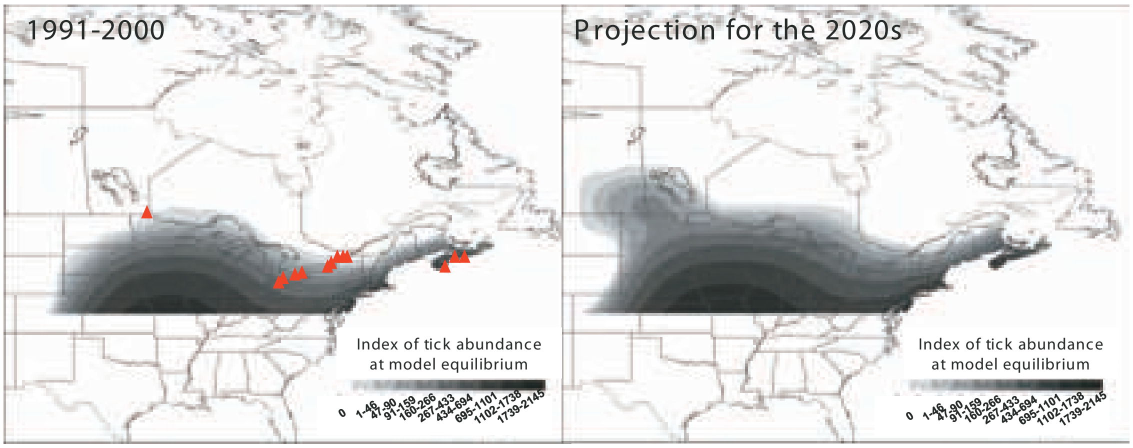
The blacklegged or deer tick, *Ixodes scapularis,* is the most common vector in North America, except on the West Coast where a related tick, *I. pacificus,* is the vector. Studies have shown that the life cycle of *I. scapularis* is temperature dependent, and warmer temperatures will shorten the tick life cycle and increase its survival (Ogden et al., 2004, 2005a). *I. pacificus* is widespread in British Columbia and its distribution may not be as greatly affected by climate, although the tick may become more common in the Canadian North and at higher altitudes, as seen with related ticks in Europe (Lindgren et al., 2000). *I. scapularis* is distributed widely across eastern and north central U.S. Tick densities and the incidence of Lyme disease continue to increase, giving rise to more cases, particularly in the northeastern and north central United States where the incidence rates and tick abundance are highest (Steere et al., 2004). Lyme disease is the most common vector-borne disease in the U.S., with up to 20,000 cases reported each year (CDC, 2004).

Resident populations of *I. scapularis* occur in Canada. Up until 1991, only one population was known to occur, at Long Point on the northern shore of Lake Erie (Lindsay et al., 1998). Since then, the number of populations has increased to 13, including those in southeastern Manitoba, southern Ontario and southeastern Nova Scotia (Barker and Lindsay, 2000; Ogden et al., 2005a; Lindsay, L.R., personal communication). Further suspected populations are under investigation. Vector surveillance over the last 17 years has identified *I. scapularis* (nearly all adults) in most populated areas of Canada from Saskatchewan east, far beyond the known resident populations (Ogden et al., 2006a). It is believed that most of these ticks are dispersed from resident populations in Canada and the U.S. by migratory birds (Ogden et al., 2006a).

Migratory birds probably facilitate the spread of ticks into southeastern Canada (Klich et al., 1996; Smith et al., 1996; Morshed et al., 1999; Scott et al., 2001). Huge numbers of birds migrate northward, from their southern wintering grounds, over southeastern Canada each year. Spring migration coincides with the seasonal activity period of nymphal *I. scapularis* in “source locations” in the U.S. and Canada (Smith et al., 1996). Many bird species make feeding stops in habitats that are densely populated with *I. scapularis.* Nymphal ticks can attach to the birds and be transported up to 800 km before dropping off their host (Scott et al., 2001; Marra et al., 2005). Ticks can thus be dispersed over great distances in spite of formidable geographic barriers, such as the Great Lakes and intensively farmed land in southern Ontario and Quebec, that would otherwise prevent dispersal on mammalian hosts.

Climate change may alter the risk of Lyme disease in Canada. Higher ambient temperatures will shorten tick life cycles, create more favourable conditions for host-seeking activity and increase tick survival (Ogden et al., 2004, 2005a). Such effects are likely to increase the probability that new tick populations become established from ticks seeded into Canadian habitats by migratory birds. Climate change is therefore likely to create additional endemic foci of tick-borne zoonoses, such as Lyme disease, beyond the current northern limit of the tick’s range (Ogden et al., 2006b) (Figure 5.3).

Figure 5.3 Model simulation results suggest that *Ixodes scapularis* populations in Canada (red triangles) occur at the limit of temperature suitability for the tick. Temperature may be a significant factor limiting northward expansion of the geographic range of *I. scapularis,* but this is expected to change rapidly with projected climate change



Source: Ogden et al., 2006b.

There is a risk of Lyme borreliosis in British Columbia because *I. pacificus,* the tick vector of Lyme disease in western North America already has a wide geographic distribution (British Columbia Centre for Disease Control, unpublished data). Despite widespread presence of the vector, efficiency of Lyme disease transmission is less than in eastern Canada. This is due to ecological differences among the ticks, such as their seasonality and their choice of hosts.

I. scapularis and *I. pacificus* are also vectors of *Babesia microti* (the pathogen causing human babesiosis), and *Anaplasma phagocytophilum* (the agent of human granulocytic anaplasmosis). Because *A. phagocytophilum, B. microti* and *B. burgdorferi* share the same rodent reservoirs and tick vectors, human co-infection with human babesiosis and Lyme disease could occur in endemic areas. The severity of symptoms and duration of illness in patients with concurrent babesiosis and Lyme disease is reported to be greater than that of either infection alone (Krause et al., 1996).

Climate change may also affect the human health risk due to a number of other infections transmissible by *I. scapularis* and other tick species in North America (Table 5.1). These include rickettsial diseases such as Rocky Mountain spotted fever (*Rickettsia rickettsii*), human granulocytic anaplasmosis (*A. phagocytophilum*) and Q fever (*Coxiella burnetii*), and tick-borne viruses (e.g. Powassan encephalitis virus) that are already present in Canada (Calisher, 1994).

Table 5.1 Diseases transmissible by *Ixodes scapularis* and other tick species in North America

Disease	Vector	Symptoms	Canadian Distribution
Tick-borne pathogens known to be endemic to Canada			
Lyme disease (*Borrelia burgdorferi*)	Blacklegged or deer tick (*Ixodes scapularis or I. pacificus*)	Skin rash, chronic arthritis, nervous system disorders, debilitation; has caused paralysis in children	Ont., N.S. and as far west as Sask. (*I. pacificus found in B.C.*)
Rocky Mountain spotted fever (*Rickettsia rickettsii*)	Rocky Mountain wood tick (*Dermacentor andersoni*) and Amercian dog tick (*D. variabilis*)	Moderate to high fever, local to widespread rash; potentially fatal if not treated	Human cases in B.C., Alta., Sask. and Ont.
Tularaemia (*Francisella tularensis*)	American dog tick (*Dermacentor variabilis*), Rocky Mountain wood tick (*D. andersoni*), blacklegged tick (*Ixodes scapularis*), other ticks	Skin ulcers, lymphadenitis, pneumonia; occasionally fatal, but can cause mild malaise and fever also	Widespread, but much of human infection via other non-tick routes
Human granulocytic anaplasmosis (*Anaplasma phagocytophilum*)	Blacklegged tick (*Ixodes scapularis*)	Mild febrile illness, but increased susceptibility to secondary infections that can be fatal	Possibly in tick-endemic localities across Canada
Q fever (*Coxiella burnetii*)	Generally through exposure to infected animal tissues or non-pasteurized milk; cases from tick bites are rare	About 50% of people infected show symptoms ranging from mild flu-like syndrome to pneumonia and hepatitis; occasionally fatal	Widespread in livestock
Powassan encephalitis virus	Rocky Mountain wood tick (*Dermacentor andersoni*), groundhog tick (*Ixodes cookei*) (*I. marxi* and *I. spinipalpus* may carry a variant Powassan virus), blacklegged tick (*I. scapularis*)	Mild fever and flu-like symptoms to encephalitis; occasionally fatal or causing long-term neurological problems	Very sporadic geographic and temporal occurrence; geographically widespread in the northern hemisphere with some human infections in Ont., the Prairies and the United States
Tick-borne pathogens known to be endemic in northeastern United States, but not known in Canada			
Human babesiosis (*Babesia microti*)	Blacklegged tick (*Ixodes scapularis*)	High fever, flu-like symptoms possibly with jaundice; severe symptoms (congestive heart failure, renal failure, acute respiratory distress syndrome) and death mostly in immunocompromised people	

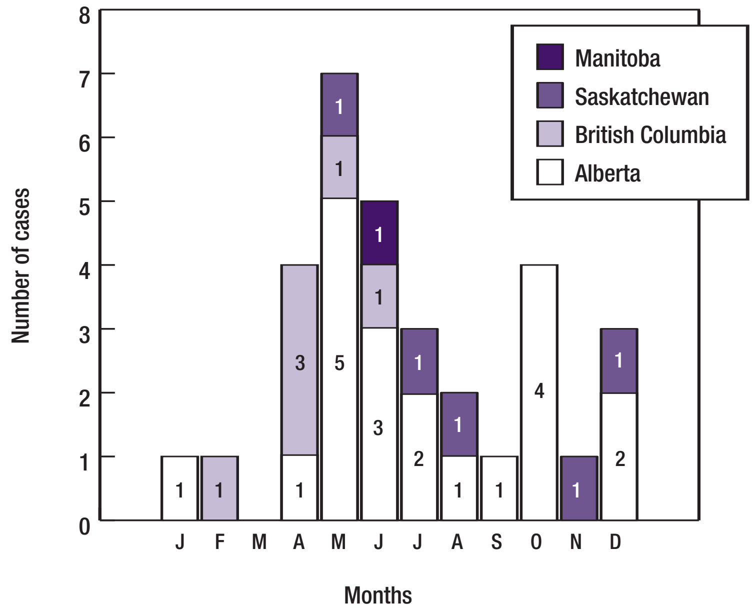
Climate change is expected to increase the risk from diseases (e.g. Lyme disease) that are associated with the tick *I. scapularis*. To what extent climate change may alter the risk from other tick-borne diseases is unknown and uninvestigated; at present, there is no infrastructure to identify any changes before human disease cases occur. The impact of tick-borne pathogens can be amplified by infection of blood used for transfusions (Cable and Leiby, 2003), as has been the case for West Nile virus (Vamvakas et al., 2006).

5.3.3 Rodent-Borne Diseases

Rodents are among the most abundant of wild animal hosts of zoonoses (Gubler et al., 2001). They are the main reservoirs of tick-borne zoonoses (as described in section 5.3.2) but are also hosts of diseases that are transmitted by close contact with humans, either by fleas or directly without the mediation of a tick or insect vector. The diseases they transmit are reviewed here because they constitute environmental health risks that may vary with climate and therefore possibly with climate change. For example, warmer winters and increased rainfall are likely to improve rodent survival, and thus the abundance of rodent reservoirs of disease may increase in some regions (Lewellen and Vessey, 1998). Extreme weather events such as high rainfall accompanied by flooding may increase the likelihood of humans coming into contact with rodents, their fleas and their potentially infective faeces and urine (Gubler et al., 2001; Karande et al., 2003). Other wild animal hosts may be important reservoirs of zoonoses, but their roles are poorly studied in general as well as in Canada. Rodent-borne diseases such as hantavirus, leptospirosis (which is also water-borne: see section 5.2.2), bartonellosis and plague are very probably common within many rodent populations in Canada. Plague and hantavirus are nationally reportable so it is known that these are rare infections in humans, presumably because contact between rodents and humans is infrequent. Leptospirosis and bartonellosis are not reportable so their incidence in Canada is unknown, but possibly underestimated (Levesque et al., 1995; Jardine et al., 2005). Furthermore, there are alternative domesticated and wild animal reservoirs for both diseases, and human disease cases may not be easily attributed to rodents alone. Even if these diseases are rare in humans in Canada, they are still of concern because all can cause serious disease in humans and some can be fatal (Gubler et al., 2001; Boulouis et al., 2005).

Hantaviruses cause infections of wild rodent and insectivorous mammal populations and can cause hantavirus pulmonary syndrome, a fever followed by acute pulmonary edema and shock. There is no specific treatment for hantavirus pulmonary syndrome; the case fatality rate is 38% in Canada (Drebot et al., 2000). Humans become infected by contact with infected rodents or their excretions, particularly aerosolized urine or feces (Weir, 2005). Thirty-six cases were reported in Canada between 1989 and 2001, or two to eight cases per year (Drebot et al., 2000). Cases seem to be confined to the western provinces (British Columbia, Alberta, Saskatchewan and Manitoba) and one case has been reported in Quebec (Weir, 2005). The presence of infected mice throughout Canada suggests that the potential for hantavirus pulmonary syndrome exists across the country (Drebot et al., 2000). In Canada, human cases tend to occur in spring and late fall (Figure 5.4), possibly a result of both human and rodent behavioural factors that increase risk of exposure.

Figure 5.4 Seasonal distribution of hantavirus pulmonary syndrome cases reported in Canada from 1989–99

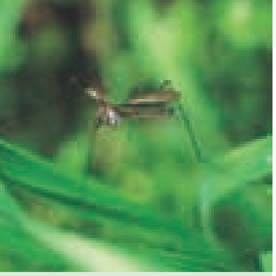


Source: Drebot et al., 2000.

Hantavirus pulmonary syndrome occurrence has been linked to an upsurge in rodent populations related to climate and ecological conditions (Wenzel, 1994; Glass et al., 2000). Mild winters and drought followed by heavy rain appears to significantly increase rodent populations and disease risk (Mills and Childs, 1998; Hjelle and Glass, 2000). Like that of other rodent-related diseases (e.g. plague, Lyme disease), the risk of hantavirus pulmonary syndrome may increase where climate change creates conditions favourable to rodent populations. Infected mice have been found in all provinces and territories except Nova Scotia, Prince Edward Island and the Yukon (Drebot et al., 2000).

Plague is caused by infection with the bacterium *Yersinia pestis*. It is maintained in rodents, and transmitted among rodents by fleas. Humans become infected most often by the bite of an infected flea. In humans, plague infections can manifest in three forms, bubonic, septicemic and pneumonic, all of which have high case-fatality rates if left untreated. *Y. pestis* is maintained in wild rodent populations in southern Alberta and Saskatchewan (Leighton et al., 2001) and in the western U.S. (Cheney, 1998). Although human cases of plague have not been reported in Canada since 1924, the World Health Organization reports 1,000 to 3,000 cases of plague worldwide every year. During recent decades, about 10 to 15 people a year have been infected with plague in California and elsewhere in the southwestern U.S. (CDC, 2005a). Changes in land-use patterns and in climate (mostly linked to the El Niño-Southern Oscillation (ENSO) ocean-current phenomenon) have been associated with an increase in plague in the U.S. in the 1980s and 1990s (Parmenter et al., 1999). Rapid urbanization in endemic areas has increased the likelihood of human-to-rodent contact and transmission of infections (Duplantier et al., 2005). The ENSO-related heavy rains of 1993 were strongly associated with increased numbers of human cases of plague, possibly by increasing available feed and winter survival of rodents, and hence their abundance (Parmenter et al., 1999). Similar effects due to increased maximum daily summer temperature values, following heavy winter rains one to two years prior, have also been suggested (Enscore et al., 2002).

The relationships between climate and rodent-borne diseases outlined here are examples, but the range of zoonoses maintained by wildlife, and potentially influenced by climate and climate change, is much wider (Bengis et al., 2004).



5.3.4 The Importation of Exotic Diseases

In the era of globalization, Canada must extend its consideration of the health impacts of climate change to an international, even global scale. The emergence of a global market place, hypermobility of goods, capital and people, and increasing access to worldwide travel and to instantaneous communication technologies have major implications for health in Canada and abroad (Labonté and Schrecker, 2006). Disease vectors can travel in boats, airplanes and suitcases, food-borne pathogens move with imported foods, and people can be carriers of pathogens. In all cases, a key issue is the speed with which exotic disease agents may move about the globe, eventually reaching Canada, as demonstrated by the West Nile virus epidemic in North America. It is thought that West Nile virus in North America originated from the import of an infected mosquito into New York on an aeroplane that came from the Middle East (Glaser, 2004). Within four years, it was endemic almost continent wide. At present, health and agricultural authorities monitor known health threats in travellers and in imported animals and foods. With climate change, expected patterns of animal and human disease may vary worldwide, resulting in a changed global landscape of health risk (McMichael et al., 2003). Significant impacts of climate change on agriculture, markets and transportation are projected for Africa and parts of Asia, with grave consequences for health in those regions (United Kingdom Department for Environment, Food and Rural Affairs, 2005; Field, 2005). Thousands of people could be displaced and Canadian trade partners could be affected, which in turn could affect conditions at home. Travelling Canadians returning with illnesses from endemic areas of the world are already a burden to local health care systems. The consequences of these global changes in disease risk for Canadians' health and health care sector are not yet well understood. Authorities responsible for disease surveillance, mitigation and treatment already monitor the immediate changes that affect health risks in the Canadian population. What is less common is the integration of future risks arising from changing climatic conditions in planning processes in order to determine future levels and responses needed, or what actions can be taken.

Canada has a very diverse population, and many people travel to visit family, vacation or conduct business across the globe. This mass movement, augmented by immigration and the deployment of military personnel, increases the potential for a person to become exposed to illnesses in one country and then to expose others to the infection in a location thousands of miles from the original source of infection. For example, travellers are estimated to run a 20-50% risk of contracting food-borne disease depending on their destination (Käferstein et al., 1997). Several hundred cases of malaria are imported into Canada each year, with peaks in imported cases mirroring epidemics elsewhere (MacLean et al., 2004). In the U.S.,

61% of cholera cases are attributed to international travel (Käferstein et al., 1997; Steinberg et al., 2001), while in Canada almost all cases are imported (PHAC, 2005a). Public health authorities at all levels of government disseminate information to travellers on health risks abroad and advocate protective measures. The timing and content of these public service messages may need to change as the geographic patterns and seasonal occurrence of exotic diseases are altered by climate change (PHAC, 2000).

Exotic diseases may pose a diagnostic challenge to physicians unaccustomed to their presenting symptoms, or unaware of the patient's travel history. The outbreak of severe acute respiratory syndrome (SARS) in Ontario and British Columbia in 2003 highlighted the difficulties of dealing with a previously unknown and infectious agent. Lessons learned will enable Canada to deal with future public health crisis situations (PHAC, 2005b). Since 2003, health care practitioners and public health practitioners have learned many lessons in dealing with highly infectious, imported diseases. Where possible, the best method of control is to inform travellers ahead of time of the potential exposure risks and recommend appropriate vaccinations or medication to prevent illness.

5.3.5 Key Knowledge Gaps

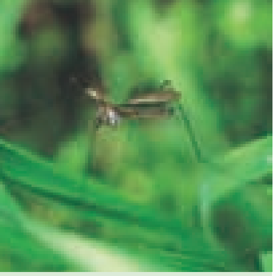
The following knowledge gaps have been identified in this review, as well as by previous studies.

Capacity

- interdisciplinary approaches are required to address the complex problems associated with research on food-, water-, vector- and rodent-borne diseases and climate change;
- researchers will need to be trained in interdisciplinary approaches;
- research networks linking this relatively small research community are vital to creating the critical mass needed to accomplish the research; and
- specialized technical expertise is needed to enhance response capacity.

Research

- the ecology of disease from the environmental source to the human case of the disease, including the ecology of hosts and vectors (this knowledge is required to identify where and how a change in climatic conditions might alter the hazards posed by these diseases);
- effects of climate and climate change in the hydrology of watersheds and other water sources (e.g. private wells, beaches, estuarine water) and on the contamination of water;
- effects of climate change on diseases, particularly vector-borne diseases, that are not yet in Canada but are geographically nearby, and on exotic vector-borne diseases where travel and unintentional vector importation are possible;
- effects of climate and climate change on transmission of pathogens in domesticated livestock and food processing, and on health risks associated with imported food and livestock;
- effects of climate change on the interaction of individual, population, ecosystem and infrastructure factors in vulnerability to infectious diseases;



- understanding the ecology of zoonoses in a wider range of wild animal hosts such as marine mammals and wild ungulates; and
- changing behaviour to reduce vulnerability to food-borne illness, particularly as it relates to cultural, social and societal preferences and food-handling and -processing norms.

Enumeration of current disease risks

More detailed quantification is needed of the infectious diseases that are affecting, or could affect, the human population in Canada. For example, the burden of illness from water-borne pathogens in Canada is not known, mostly because of source attribution problems; gastrointestinal infections can be transmitted person to person, in water and in food (Mead et al., 1999), and investigation of the source of endemic cases is not as routine. Perhaps only one out of 300 gastrointestinal infections are reported (Majowicz et al., 2004), which seriously limits burden of illness estimates. The geographic distribution of zoonoses in wildlife and of vectors is poorly understood, which limits the power to predict human populations at risk if effects of climate change on risk were to be identified.

Assessment of surveillance systems

There is a need to assess the adequacy of surveillance systems to detect significant changes in the incidence and geographic distribution of pathogens in humans and in important sentinel non-human species. At the 2006 Canadian National Consensus Conference on Lyme disease, current surveillance case definitions, which rely on current knowledge of endemic areas, were identified as a potential obstacle to identifying the new endemic areas that are anticipated to arise as a consequence of climate change.

Development of warning systems

There is a need to improve the linkage between pathogen surveillance and meteorological information where climate is an indicator for a potential disease event. There is a pressing need to develop a better understanding of the impacts of extreme weather events on public health infrastructure and vulnerability to infectious disease outbreaks in order to develop warning systems. For example, heavy rainfall may contribute to water supply contamination as well as provide breeding areas for mosquitoes.

Chapter 5

5.4 ADAPTING TO CLIMATE CHANGE: RISK ASSESSMENT, SURVEILLANCE, INTERVENTION AND ADAPTATION

Existing health and public health systems already protect Canadians from many disease risks by identifying risks and carrying out surveillance, interventions, and the diagnosis and treatment of infected and infectious individuals. Previous sections have reviewed current knowledge on the potential effects of climate change on water-, food-, vector- and rodent-borne disease risks in Canada. However, the extent of climate change effects on health risks and the challenge they pose to existing health and public health systems still need to be fully investigated.

This analysis reflects the knowledge of the effectiveness of current measures that help individuals reduce exposure to risks, mitigate and manage these risks and provide adequate, appropriate diagnosis and treatment. The next steps in minimizing the potential increases in these risks are:

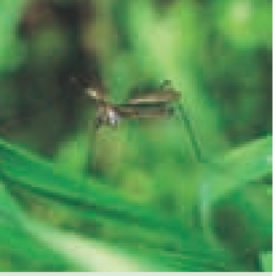
- determining baseline data on infectious disease occurrence and the associated burden of illness;
- a comprehensive risk assessment to prioritize public health threats for action; and
- a consultative approach to adaptation via:
  - enhanced surveillance
  - targeted intervention.

5.4.1 Risk Assessment

A risk assessment comprises four elements to estimate the likelihood and severity of risk: hazard identification; exposure assessment; dose-response assessment or hazard characterization; and risk characterization (Coleman and Marks, 1999). Risk assessment methods are used to prioritize risks and hazards and to help with policy development (Gibson et al., 1998).

The broad review of potential health risks associated with climate change, presented here, is a first step in a rational approach to preparing for these risks. However, a more far-reaching and systematic risk assessment is required to identify priorities for action. One way of structuring the many decisions involved, the capturing of the information on which to base those decisions and the many answers often required, is through a multi-criteria decision analysis (MCDA). It is used increasingly to aid decision making in environmental health (Linkov et al., 2006). MCDA is a useful vehicle to capture the many decisions and many possible answers involved in risk assessment across the country. MCDA sets out an explicit pathway for identifying the criteria for selection and ranking, for weighting these criteria according to the requirements and objectives of different stakeholders, and then for analyzing and ranking on the basis of all criteria and weights. In the climate change context, there are likely many criteria in selecting and ranking disease risks, but examples include the following:

- Pathogenicity: More pathogenic or lethal pathogens may merit particular attention.
- Estimated case numbers and incidence rates: How common diseases are, or are likely to become, may affect their priority.



- Probability that risks are realized: Confidence that climate change will cause a change in risk, or cause a new risk to emerge, may vary among different pathogens.
- Immediacy of risk: Some disease risks may be more immediate because they are geographically close to Canadian populations at risk or are likely to be affected first by climate change.

The need to understand climatic drivers for current disease patterns, so that effects of climate change can be predicted to inform the risk assessment process, presents a key public health challenge. The case has been made for the use of process-based simulation models that use understanding of the ecology of vectors and pathogenic microparasites to predict their occurrence in time and space (Kurtenbach et al., 2006). Such models have already been developed for some vector-borne and enteric pathogens (Bigras-Poulin et al., 2004; Ogden et al., 2005a, 2007). Where the detailed data on the ecology of vectors and microorganisms are not available, statistical models that demonstrate associations between disease incidence and climate variables can be used to predict or estimate climate change effects (Fleury et al., 2006; Thomas et al., 2006). However, in either case researchers have just begun to scratch the surface in terms of gathering the information required for comprehensive projections of the wide range of infectious disease risks that may arise in Canada due to climate change.

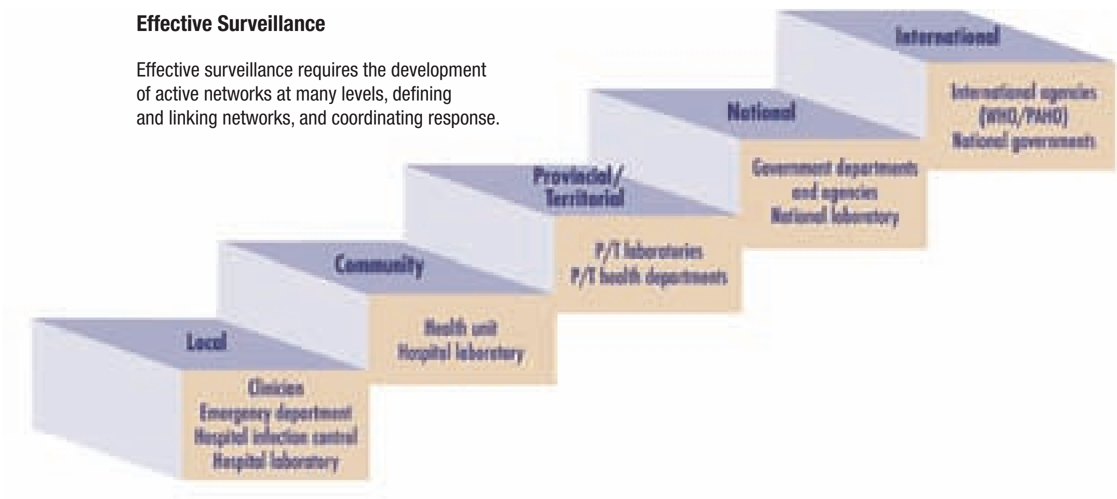
Once key selection criteria have been identified, these need to be weighted according to the importance allotted to each criterion by stakeholders that reflect the diversity of the Canadian population. For example, in contrast to urban water supplies, water treatment in smaller systems or rural areas generally does not have the same resilience and redundancies, the tax base to support large financial investments, or the same accompanying access to health care. As well as these community risks, individuals at risk of food- and water-borne disease include the young, seniors and immunocompromised individuals (Rosenberg et al., 1997). Some Canadians are more vulnerable than others to mosquito- or tick-borne diseases because of their age or health status, outdoor occupation or activities, or because they live in areas with abundant tick or mosquito populations. Risk groups include outdoor enthusiasts and members of Aboriginal communities, particularly those pursuing traditional livelihoods. Arctic communities may face threats from vector-borne diseases as the climate warms rapidly in the North (Berner et al., 2005).

5.4.2 Surveillance

Once key health risks have been identified and prioritized, the next process is to establish that surveillance systems are (i) capable of identifying changing disease patterns and emerging risks in a timely fashion, and (ii) able to trigger appropriate interventions to control disease risks, again in a timely fashion.

In Canada, disease surveillance has moved from the traditional work of recording past events to a more active, anticipatory approach designed to identify health threats as early as possible. To be effective, such an approach requires a collaborative effort among health professionals and their allies at all levels of government, as well as internationally (Figure 5.5). Surveillance needs to be linked more tightly to action with a feedback loop at each scale for all surveillance programs. For example, individuals and public health units may not report a disease unless they see a benefit or the broader impacts on health. Local, provincial and federal health departments each maintain registries of health data on certain diseases, infections, hospitalizations and injuries, while the World Health Organization monitors similar data at a global level. These data, collected by recording events as they occur, contribute to passive surveillance and may be enhanced by active surveillance programs that obtain data on particular health problems (e.g. emerging infections) (Pinner et al., 2003). The creation of the Public Health Agency of Canada was a major step toward improving infectious disease surveillance and control, and the National Notifiable Diseases On-Line and the *Canadian Communicable Disease Report* allow access to information on case reports and surveillance results of infectious diseases.

Figure 5.5 Effective surveillance framework



Note: P/T, provincial and territorial; WHO, World Health Organization; PAHO, Pan American Health Organization.

Source: Charron and Sockett, 2005.

As well as tracking individual human disease cases, a number of alternate surveillance activities can be useful in identifying disease risks and triggering interventions. These include monitoring zoonotic diseases (diseases transmissible between animals and people) in sentinel animal and vector populations. For example, Canadian public health authorities routinely monitor West Nile virus activity in birds and mosquitoes to measure the human health risk (PHAC, 2006). A resurgence of leptospirosis in domestic dogs in Canada may prove to be both a sentinel for increased human risk from wildlife sources of the disease and a potential source itself (Hrinivitch and Prescott, 1997; Carmichael, 1999; Kalin et al., 1999; Prescott et al., 1999; Warshawsky et al., 2000; Prescott et al., 2002). Research is also underway to understand how trends in over-the-counter medication (e.g. antidiarrhoeal remedies) may help detect water-borne illness in communities (Edge et al., 2004). Newspapers have also been useful in monitoring health problems related to extreme weather events (Soskolne et al., 2004). The importance of alternative systems of surveillance such as these is likely to increase due to global environmental change in times of competing demands on limited resources. Local communities may also contribute helpful information often not captured by health surveillance activities alone. Sources such as these are especially important when studying the impacts of weather and climate on health. For example, First Nations elders may contribute pertinent observations on changes taking place in their communities and environments (MacKinnon, 2005). Farmers may understand the significance of weather patterns and can provide useful insights regarding health impacts. Similarly, hunters and fishers may observe changes in the health of wildlife that represent a human health risk (Sang et al., 2004).

Adapting surveillance systems to increased or altered health risks due to climate change will require imaginative development and intelligent use of both current and new surveillance methods. The process of surveillance method selection will be an MCDA that engages a wide variety of stakeholders. In the climate change context, surveillance systems must be dynamic and capable of responding to observed changes or to projections obtained from simulation or statistical models. In either case, increasing capacity to link these to geographic information systems technology provides powerful tools to direct and rationalize surveillance activities once they have been developed.

5.4.3 Intervention and Adaptation

The Canadian public health and health care infrastructures have evolved over many years, and in many ways, to reduce the health risks related to weather and climate. Provinces have vested authority in Medical Officers of Health to issue boil water advisories under adverse water quality situations; the federal government operates a centre for emergency preparedness and response; and various non-government organizations have delivered public education and outreach on a range of related topics. As a result, Canadians are generally well protected from current weather- and climate-related health risks. For example, during floods or high-impact rain events, the contamination of surface water and compromised wells is widely assumed, and boil water advisories are issued. The most recent example in Canada was an advisory for the Greater Vancouver Regional District in British Columbia in November 2006. A large storm event caused extremely high turbidity in the systems reservoirs and a precautionary advisory was issued and was in effect for 12 days (CBC News, 2006). A similar situation occurred in the Red River Valley, southeastern Manitoba, as a result of the flood of 1997; the flood caused no direct loss of life, but resulted in property damage and the evacuation of 28,000 people from their homes (Burn and Goel, 2001).

Water- and food-borne diseases

The systems in place to help to manage existing water- and food-borne diseases provide the foundation for dealing with the new water- and food-borne health impacts related to climate change. In general, methods of control of water- and food-borne diseases are well established. Key aspects of controlling microbial drinking water contamination include a multiple barrier approach, with emphasis on source-water protection, and site-specific water treatment technologies with built-in redundancies (source-to-tap initiatives). Existing water treatment and food-processing regulations (e.g. Hazard Analysis and Critical Control Point) may well be robust in the face of climate change. Furthermore, many of the measures already in place to reduce weather-related health risks (e.g. severe weather warnings, boil water advisories, monitoring and surveillance, emergency preparedness) will continue to offer protection from the same risks under a changed climate. However, these systems are by no means comprehensive. For example, it is still impossible to calculate the burden of illness associated with water-borne disease under current data collection and reporting formats. Food-borne disease outbreaks continue to be observed despite these systems, such as the 2006 fresh spinach outbreak (CDC, 2006b). Furthermore, as the climate continues to change, some of these systems may reach or exceed the limits of their effectiveness.

In assessing the capacity of drinking-water systems to respond to new challenges with climate change, a number of criteria need to be examined, including design, redundancy, resilience and maintenance issues. Infrastructure and processes are designed to a maximum threshold based on historical climate records. As rainfall events intensify and become more frequent, existing multiple safety barriers may fail more often or require greater maintenance (Watt et al., 2003), increasing the risk for contamination and subsequent disease. For example, the 2001 Battlefords (Saskatchewan) *Cryptosporidium* outbreak occurred because the water treatment

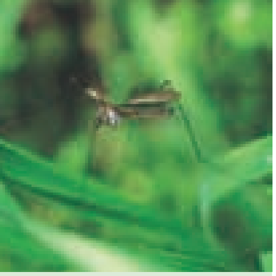
was functioning at a sub-optimal level. The source water was contaminated through poor location choice (downstream from the sewage discharge pipe), and weather impacts affected water quality (Stirling et al., 2001). The encysted stages of *Cryptosporidium* and some strains of *Giardia* are known to be resistant to simple chlorination water treatment. In general, *Giardia* can be inactivated with chlorine, but the chemical concentrations and contact times required make it an inefficient treatment method in most cases (Hibler et al., 1987; Korich et al., 1990). Canada's aging and increasingly urban population puts more people at risk; aging and deteriorating infrastructure may compromise the reliability of water treatment systems (Schuster et al., 2005); and the robustness of such systems will influence how well they can respond to new health risks. Individual contaminants have their own idiosyncrasies that must be taken into account in planning. These demographic, geographic and contaminant-based variations in risk and intervention requirements must be taken into account via stakeholder-driven weighting of criteria for selection of intervention methods.

Vector- and rodent-borne diseases

Some of the pathogens responsible for vector- and rodent-borne diseases are endemic to Canada, but many risks associated with climate change involve emergence of pathogens new to Canada. These are likely to require different interventions (i.e. the prevention of epidemics and spread–and even eradication–of newly emerging pathogens versus minimizing risks from endemic diseases). In both cases, the methods, intensity and point of use of interventions will be highly variable and pathogen specific. Again, criteria for interventions need to be established and weighted according to pathogen, objective, location and populations at risk in a stakeholder-led process. For example, populations susceptible to Lyme disease include people who spend time in woodlands and woodland-edge environments, outdoor workers, outdoor sports enthusiasts, dog owners, hunters and hikers, as well as rural and suburban home owners and their families (Dister et al., 1997).

Available interventions are those generally borrowed from regions where vector- or rodent-borne pathogens are currently a problem and endemic. In almost all cases, there are no vaccines available and none are likely to become available in the foreseeable future. Interventions rest on vector control or public health messages, as exemplified by the response to the West Nile virus in recent years. In this outbreak, provincial and municipal health authorities made considerable efforts to control mosquitoes by destroying larval mosquitoes with biological or chemical larvacides and by killing adult mosquitoes with residual (applied to surfaces) or broadcast (in the air) adulticides (Nasci et al., 2001; Thier, 2001; Herrington, 2003; Shapiro and Micucci, 2003). Public health messages were put in place to reduce mosquito larval development sites, such as standing water, and reduce human biting. The latter included advice on using mosquito repellents, wearing protective clothing, avoiding outdoor activities at dusk and dawn, when mosquitoes are most active, and limiting activity in areas where mosquitoes are abundant (Moore, 2003).

Tick-borne diseases can similarly be controlled by a variety of vector control methods and by the vaccination of wild host species (Schmidt and Ostfeld, 2001; Dolan et al., 2004; Rand et al., 2004; Tsao et al., 2004; Schulze et al., 2005). Experiences from other countries suggest caution in the chemical control of ticks (Ogden et al., 2005b). Public health messaging is again important because tick bites and tick-borne infections can be avoided by wearing suitably protective clothing, and by checking for ticks on clothing and the body after being in tick habitats (Health Canada, 2006). Public health messaging about vector-borne disease symptoms may also limit the impact of these diseases. For example, early Lyme disease is often easily diagnosed by clinicians and usually readily cured with antibiotics. Later-stage infections are more difficult to diagnose and treat, and cause considerable debilitation in affected patients (Wormser, 2005).



5.5 CONCLUSIONS

This chapter has identified that the potential exists for climate change to affect public health in Canada, via effects on the risk from food-, water-, rodent- and vector-borne diseases. It is essential to act upon these observations and to prepare for coming risks and challenges. A range of actions should be considered, including assessment of risks and risk-management measures through the establishment of necessary surveillance systems linked to effective intervention and control processes. As well, training of professionals and public education aimed at the adoption of behaviours to minimize health risks is necessary. The Public Health Agency of Canada is strategically placed to take a lead role in this process in partnerships with federal organizations such as Health Canada, the Canadian Food Inspection Agency, non-government organizations, research networks (e.g. Canadian Water Network, ArcticNet) and public health organizations in provinces, territories and municipalities. A wider engagement of stakeholders from different cultural, geographic and demographic groups is essential to create the diversity of opinion needed to develop and implement inclusive and adaptive mechanisms to protect the Canadian public.

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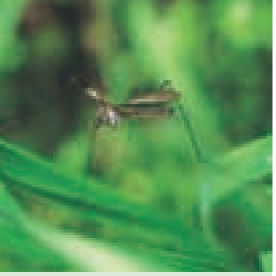

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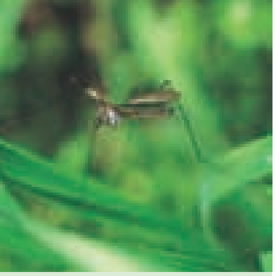

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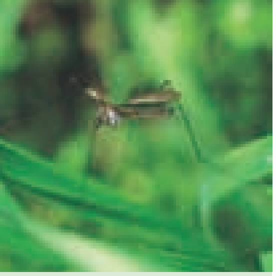

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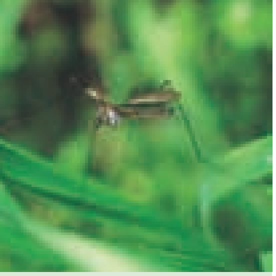

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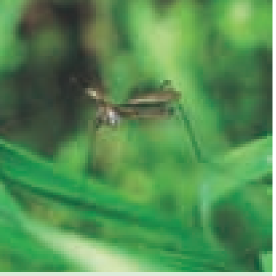

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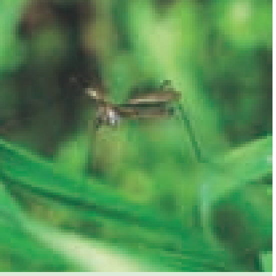

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Chapter 6

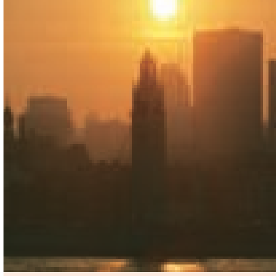
Health Impacts of Climate Change in Quebec

Pierre Gosselin

Diane Bélanger

Bernard Doyon

Contributors:
Mélissa Giguère
Marie-Andrée Lévesque



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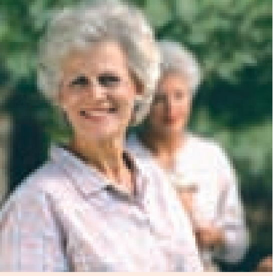
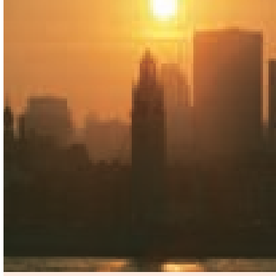




Chapter 6

6.1 INTRODUCTION

When Health Canada decided to launch *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity* in 2003, several factors contributed to the development of a more detailed regional component that addressed Quebec.

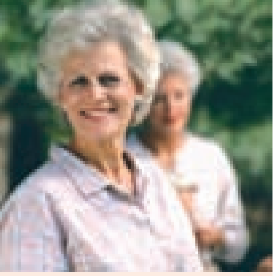
Research projects on the health impacts of climate change have been underway since 1999. They have addressed several themes (northern environments, airborne organic particulates such as pollen, crime, the effects of heat waves), with the support of the Canadian Climate Impacts and Adaptation Research Network (C-CIARN), Health Canada, the *Ministère de la Santé et des Services sociaux* (Quebec department of health and social services) (MSSS) and the Ouranos Consortium (Ouranos).[1] In addition, these partners discussed other initiatives—in particular, adaptation to climate change by the public and related public services, and modelling of climate change on a finer scale than global climate models to predict future health impacts, along with several other projects. This research was intended to foster a better understanding of public health adaptation measures in the near future and to facilitate their implementation.

The severe European heat wave in summer 2003 was a pivotal incentive to further action by these partners, and prompted a more detailed look at Quebec. This extreme climate event (ECE) joined others that had deeply affected Canadians in the past decade: the 1996 floods in Saguenay and the 1998 Ice Storm that primarily affected the region south of Montreal. These events cost taxpayers and organizations several billion dollars, and there were other non-monetary costs that perhaps were longer lasting. The number of Quebeckers (currently 90%) in favour of international commitments to greenhouse gas (GHG) reduction (Centre de recherche sur l'opinion publique (CROP), 2002) was also a determining factor in going ahead with this research on adaptation to the health-related effects of climate change in Quebec.

In fall 2003, MSSS formed a five-year partnership with Ouranos. In the beginning of 2004, the ministry formally asked eight regional public health departments to implement, no later than 2007, emergency intervention plans in case of severe heat waves. At the same time, the Institut national de santé publique du Québec (Quebec national institute of public health) (INSPQ) was asked to conduct several research projects on impacts and adaptations in cooperation with Ouranos, and to coordinate the related research with the public health network, universities and Health Canada.

It was possible to launch such an assessment for Quebec because of the well-developed governance for public health interventions already active on climate change. The presence of Ouranos, and its multi- and interdisciplinary approach linking the climate sciences and research on adaptations, enabled the mobilization of resources and competencies in this area.

1 Ouranos is a research consortium created in 2001; it studies regional climatology and adaptation to climate change, focusing primarily on Quebec, but it is also active nationally and internationally (Ouranos, 2004)



In addition, recent Quebec reforms in health surveillance and emergency management, as well as an existing public health network active at the sub-regional level on climate change issues, are all underlying reasons for this more detailed regional approach.

There are seven sections in this chapter, including the introduction. Section 6.2 presents contextual data to describe some of the province's basic geographic, socio-economic, administrative and health characteristics to provide some background for the sections that follow. The next sections address research that was conducted for this chapter. Section 6.3 is an overview of the useful public health adaptation activities that already exist. Section 6.4 reports some of the results of a modelling of historic mortality for the period from 1981 to 2001, with future simulations for 2020, 2050 and 2080, using two climatic scenarios. Section 6.5 refers to investigations into climate change-related perceptions and adaptations among Quebeckers, and Section 6.6 to those among municipal and health managers. Section 6.7 presents a synthesis of the current situation, a summary of the key findings, and recommendations or suggestions for future steps for public health adaptation to climate change.

Note that northern Quebec (located above the 50th parallel), which includes the vast James Bay, Hudson Bay and Ungava regions (Figure 6.1), is not discussed in this chapter because the impact assessment for northern Quebec appears in Chapter 7, Health Impacts of Climate Change in Canada's North.

6.2 A BRIEF LOOK AT QUEBEC

6.2.1 Geography

Quebec is one of 10 Canadian provinces. It is 1,667,441 km^2 in size, and is located between 45° and 62° latitude north and between 57° and 79° longitude west. More than 99% of Quebeckers live south of the 50th parallel (Government of Quebec, 2006d). The province is bounded by the Arctic Ocean to the north, the United States (U.S.) and the province of New Brunswick to the south, James and Hudson Bays and Ontario to the west, and by the Atlantic Ocean and Labrador to the east. The topography is rather flat and there is a very well-developed highway network. The area includes 3% of the earth's freshwater reserves (Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP), 2002b). The 3,058-km-long St. Lawrence River is the most important waterway in Quebec. More than 80% of the population lives along its shores or those of its tributaries, and more than 50% of Quebeckers draw their drinking water from this river.

Quebec has a diverse climate with four distinct seasons. Depending on the latitude, average temperatures in summer vary between 5 and 20°C and in winter from -25 to -10°C. Total annual precipitation (rain and snow) also varies depending on the region, with accumulation from 500 to 1,200 mm. There are four main types of climate in Quebec: a temperate humid continental climate south of the 50th parallel, a sub-arctic climate characterized by colder temperatures and less precipitation in the North, an arctic climate in the far North and a maritime climate in the Gulf of St. Lawrence region.

The diverse climate supports several types of vegetation, from deciduous forest in the south and, progressing northward, a mixed forest zone, a boreal forest zone, taiga forest and then tundra in the far North. Forests cover more than half the province; the population is concentrated in the deciduous and mixed forest zones.

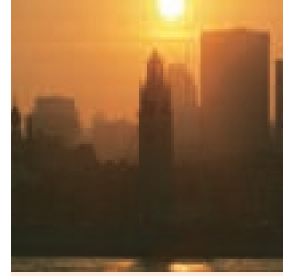


Figure 6.1 Quebec

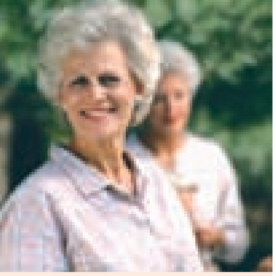
Note: The 50th parallel is located between Sept-Iles and Matagami.

6.2.2 Basic Socio-Economic Data

6.2.2.1 Population and demography

In 2006, the population of Quebec was 7.6 million, 3.6 million of whom live in the Greater Montreal area. This region has an area of approximately 4,000 km^2 and its municipalities are distributed over five administrative regions (Ville de Montréal, 2005; Institut de la statistique du Québec (ISQ), 2006f). Overall demographic density is very low, with 5.8 inhabitants per km^2, but the density is 36 inhabitants per km^2 for permanently inhabited areas. In addition to a Francophone majority (82%), there is an Anglophone community of approximately 590,000 people, close to 600,000 recently arrived allophones and approximately 80,000 Aboriginal people (Amerindian and Inuit).The Aboriginal population generally lives on reserves or in settlements administered by a band council. Inuit people inhabit the far North and live in villages directed by a mayor and councillors. Ethnic communities, other than French or English, represent approximately 18% of the Quebec population (ISQ, 2003b). Quebec receives some 40,000 immigrants annually; in 2001, these were mainly European (40.3%), Asian (26.9%), African (11.5%) and American (11.2%).

The territory is divided into 17 administrative regions, 103 regional county municipalities, 1,264 municipalities and 78 Amerindian territories. Nine municipalities (Montreal, Quebec, Longueuil, Laval, Gatineau, Sherbrooke, Saguenay, Lévis and Trois-Rivières) have more



than 100,000 inhabitants. Migration to the Montreal region and its bordering regions and the Outaouais has begun and is expected to continue for the next 20 years. The Montreal Census Metropolitan Area has the greatest linguistic and ethnic diversity, with 67% speaking French as their first language and 12% speaking English (ISQ, 2006e). The non-official languages most frequently spoken in Quebec are Spanish (3.2%), Italian (2.7%) and Arabic (1.6%) (Canadian Heritage, 2006).

As in most industrialized countries, Quebec's population is aging, with an average age of 39.3 years in 2004. Demographic trends (fertility, mortality, migration) indicate that the population will become one of the oldest in the world in approximately 40 years. In 1986, there were seven people between the ages of 15 and 64 for each person 65 years and older; projections for 2031 indicate there will be only 2.2 (ISQ, 2003a; Government of Quebec, 2006c).

6.2.2.2 Economy

Quebec had a gross domestic product (GDP) of more than C$250 billion in chained (2002) dollars in December 2005, or approximately 20% of the total Canadian GDP (ISQ, 2006b). Almost three quarters of this comes from the service sector. Quebec's GDP ranks it alongside the 20 most industrialized member countries in the Organisation for Economic Co-operation and Development (OECD). The Quebec per-person GDP may be compared with that of England and Japan; it is almost 5% greater than that of the 20 most industrialized OECD countries. However, disposable income[2] per person is still about 8 to 10% lower than the Canadian average, based on historic data. It was estimated at C$23,240 per person in 2006 (ISQ, 2006a).

Each of Quebec's administrative regions has strong economies in the science and technology sector (aerospace, information technology, biotechnology, ground transportation materials, forest products, pharmaceuticals) and in tourism; 27.5 million tourists visit Quebec annually and close to 130,000 people work in some 30,000 tourism-related businesses. Natural resources (forestry and mining) and energy resources are also at the heart of the Quebec economy. Hydroelectricity accounts for 96% of electricity production. This high percentage occurs only rarely elsewhere in the world (Manitoba, 99%; Norway, more than 99%) (Energy Information Administration, 2002; Manitoba Energy, Science and Technology, 2003). Peak demand is in winter, and a great many homes use electric heat. Quebec mineral resources rank it among the world's 10 major mining producers. There is currently an increase in exports as a result of international trade agreements and the North American Free Trade Agreement, which have increased Quebec's ability to compete on the international market. The U.S. is Quebec's principal economic partner (88% of exports). Total exports from Quebec in 2006 were valued at C$150 billion, or approximately 54% of its GDP (Ministère du Développement économique, de l'Innovation et de l'Exportation, 2007).

6.2.3 Health Administration Organization

Health and social services are combined under one administration, the MSSS, and are divided into central, regional and local levels (Figure 6.2). Quebec has 18 socio-health regions governed by the *Agences de la santé et des services sociaux* (health and social services agencies), within which are the *Directions de santé publique* (public health branches). These regions are the same as the governmental administrative regions, with the exception of Mauricie and Centre du Québec, which form one socio-health region, and the northern Quebec administrative region, which is divided into three parts (Nunavik, Terres-Cries-de-la-Baie-James and Nord-du-Québec) mainly because of the size of the territory and the ethnocultural characteristics of the population.

2 Disposable income is defined as the balance of personal income after direct individual income tax and various other fees, licences and permits, including hospital and health insurance premiums, and excluding indirect taxes. Disposable income is more discretionary than personal income (Eco-Santé, 2005b).

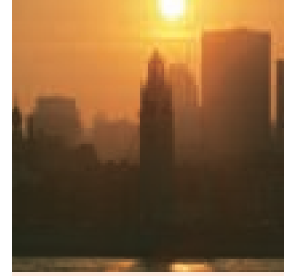
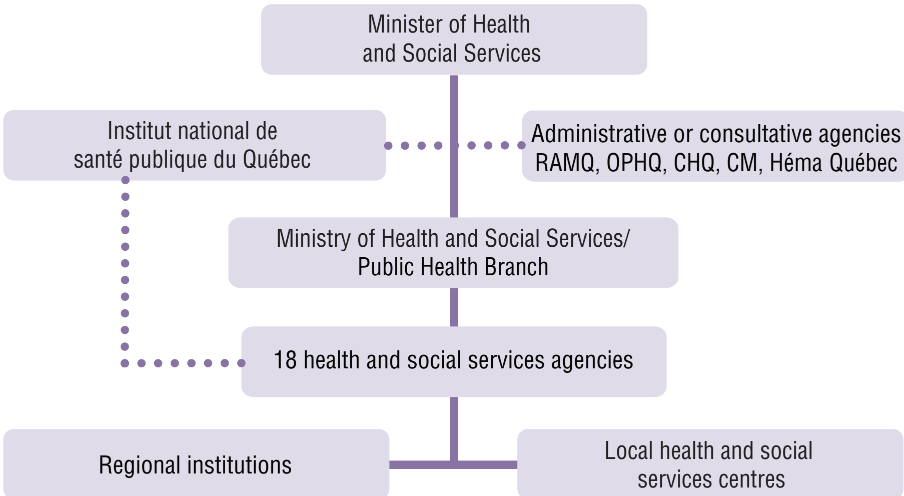


Figure 6.2 Public health within the Quebec health and social services system



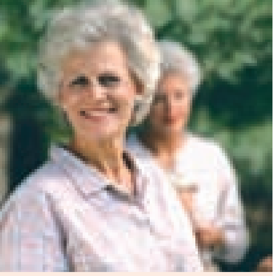
RAMQ: Régie de l'Assurance-maladie du Québec (Quebec health insurance board)
OPHQ: Office des personnes handicapées du Québec (Quebec office for the disabled)
CHQ: Corporation d'hébergement du Québec (Quebec accommodations corporation)
CM: Conseil du medicament (medication board)

Source: MSSS, 2005.

At the provincial level, MSSS establishes the general direction and allocates budget resources. At the regional level, the *Agences de la santé et des services sociaux* are responsible for regional planning and resource management, as well as budget allocations to institutions. At the local level, the 95 *Centres de santé et de services sociaux* (CSSSs) (health and social services centres) and other stakeholders share responsibility for the local population through a clinical and organizational project. A regional public health branch within each agency coordinates regional public health program activities, in cooperation with the CSSSs and other partners outside the health network. The regional director of public health is directly appointed by the minister on the recommendation of the regional agency, and has a great deal of professional latitude within the legislative framework.

The public health network also relies on INSPQ and its mandate to improve the population's health and well-being (INSPQ, 2006c). INSPQ has more than 500 employees and provides MSSS and the regional agencies with support in the form of expertise, research, laboratories, training and international affairs. For 20 some years, roundtables on public health, occupational health, environmental health, infectious diseases, health surveillance and health promotion have helped to coordinate the various public health sector stakeholders. A permanent secretariat periodically assembles representatives from the 18 regions, from INSPQ and MSSS, as well as several guests, depending on the files, for the roundtables. These meetings help to coordinate, plan, transfer knowledge and share resources.

In December 2005, the Quebec health and social services network included 315 institutions, 199 of which were public. These include health and social services centres (acute hospital services, home care, social services), university hospitals, youth centres, rehabilitation centres, long-term hospitalization centres and nursing homes. The remaining 116 institutions are privately owned and are almost exclusively long-term care facilities. There are also approximately 1,500 private medical clinics and 4,000 community organizations active in health and community services. Almost 7% of the Quebec labour force (approximately 250,000 people) work in health and social services. Each of the 18 socio-health regions includes one or more CSSS, hospitals, rehabilitation centres, and child and youth protection centres.



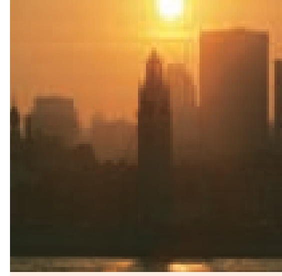
6.2.4 Public Health Goals and Programs of Interest

The *Loi sur la santé publique* (Quebec public health act), which came into effect in December 2001, is intended to protect and maintain public health through a provincial health program, regional action plans and increased health surveillance. In 2003, the *Programme national de santé publique (2003–2012)* (provincial public health program) was launched. Its general objective is to improve determinants of health and well-being by reducing health and psychosocial problems and trauma. In the context of climate change, the maintenance of air quality, surveillance of infectious diseases and reduction of poverty are very relevant. These issues are addressed specifically through research and innovation as well as through environmental health intervention (MSSS, 2003b). INSPQ is involved in research, which includes working on climate change, training researchers and publishing their work (INSPQ, 2006a).

6.2.5 Other Provincial and Municipal Policies

Various governmental policies on social housing, emergency preparedness, water management and sustainable development complement the above-mentioned public health programs in being able to implement steps that are needed to address climate change. The Société d'habitation du Québec (SHQ) (Quebec housing corporation) administers several programs to improve the supply and quality of social housing in Quebec (SHQ, 2006). Since 2001, the *Civil Protection Act* has defined areas of organization and action for organizations and agencies responsible for civil protection, as well as their responsibilities, such as those of municipalities in implementing their emergency plans (Ministère de la Sécurité publique (MSP), 2005). Section 16 of the Act obliges municipalities to define their objectives for reducing vulnerability to risks associated with major disasters, and to identify actions required to achieve these objectives. This change focuses on prevention versus reaction (i.e. reacting to disasters).

In 2002, the *Ministère du Développement durable de l'Environnement et des Parcs* (MDDEP) adopted the water policy (*Politique nationale de l'eau*), which is a comprehensive synthesis of water issues in Quebec (MDDEP, 2002c). As a result of this policy, changes were made to regulations on the quality of drinking water to ensure that small distribution networks provided quality drinking water and that water treatment plant employees were appropriately trained (MDDEP, 2005b). An international agreement on sustainable water resources in the Great Lakes-St. Lawrence River Basin was signed by two Canadian provinces (one of which was Quebec) and eight U.S. states (MDDEP, 2005c). The purpose of the recent *Loi sur le développement durable* (sustainable development act) is to guide sustainable development in Quebec; it is a first step toward a sustainable development policy (MDDEP, 2006a). The most recent Policy on Health and Well-Being dates back to 1992 and does not include measures to address climate change (MSSS, 1992). However, public health measures are outlined in the Government of Quebec Climate Change Action Plan 2006–2012, announced at the end of June 2006 (Government of Quebec, 2006e), and are discussed in the following two sections.



Certain municipal initiatives should also be recognized. Because of their responsibilities in land use and urban planning, municipalities are responsible for zoning. Many are currently revising urban boundaries within which future construction of all types will be permitted. The use of new flood-risk area maps will also be considered more frequently over the next few years. The *Union des municipalités du Québec* (UMQ) (association of Quebec municipalities) has also adopted a number of policies and programs on climate change. The *GES-Énergie municipalités* (GHG-municipal energy) program aims to reduce municipal GHG emissions. More than 200 municipalities already participate in the program (UMQ, 2006). For example, in 2004, Quebec City adopted a plan to reduce GHG emissions by 22% by 2010 (Ville de Québec, 2004). This plan has already begun to yield results (Ville de Québec, 2006). The key roles that municipalities play in developing and implementing recycling, transportation and environmental policies, as well as in the leadership of emergency preparedness plans, make them key players in adapting to climate change.

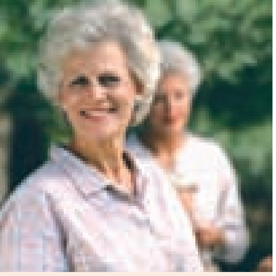
6.2.6 Status of Surveillance and Monitoring

The provincial public health program includes a surveillance program to learn about and share information on the status of population health, including the acquisition, production and distribution of data (MSSS, 2003b). The current surveillance program tracks more than 150 indicators (mortality, morbidity, health determinants, services, etc.), and will develop several dozen more over the next five years. The program could be adapted for the surveillance of health issues related to climate change because of its flexibility in analyzing priority or emerging issues, and its capability for prospective analyses (simulations) targeting certain health issues.

In 2004, INSPQ's *Infocentre de santé publique* (public health information centre) centralized data acquisition and implemented provincial surveillance tools—an essential step to understanding health problems on a large scale. All large databanks are now, or will be, hosted by INSPQ (or accessible under agreements with INSPQ), including data on meteorology, climate simulations, environmental pollution, etc.. The current plan provides for the development of indicators related to climate change within the *Infocentre de santé publique.* These will include a component that incorporates spatial and temporal analyses related to climate for some notifiable diseases, the implementation of a system for the surveillance of physical and mental health during ECEs, and improvements to the alert system for heat waves for a coordinated, real-time follow-up. INSPQ is also participating in the development of an Internet atlas of public health vulnerability to climate change (Gosselin, 2005). All these recent initiatives will be implemented between 2006 and 2012.

6.2.7 Ouranos Consortium and Public Health

The Ouranos Consortium is a multidisciplinary research and development (R&D) organization that studies climate change and adaptation; it includes some 250 scientists from 10 provincial ministries, one federal department, a Crown corporation (Hydro-Québec) and four universities. MSSS became a formal member in 2004, although it had been involved in joint health projects since 2002. Research activities include 10 programs and approximately 60 projects, 10 of which are part of the 2006–2009 health plan adopted in March 2006. MSSS has mandated INSPQ to coordinate and conduct part of the research on the health effects of climate change and required adaptations, in cooperation with regions, Ouranos partners and Health Canada.



6.3 STATUS OF CLIMATE CHANGE ADAPTATION INITIATIVES, 2004–07

6.3.1 Context

Climate change will have diverse effects. According to international authorities (World Health Organization (WHO), 2003; United Nations, 2007a, 2007b) and several multinational corporations (Earth Institute, 2007), proactive solutions to create measures to adapt to and mitigate the impacts must be implemented immediately. National and international health authorities have targeted six areas essential to human health: heat waves and urban heat islands; preparation for extreme climatic events (ECEs); water and food; vector-borne and zoonotic diseases (WHO, 2003; Warren et al., 2004; Menne and Ebi, 2006); exposure to ultraviolet (UV) rays; and air quality. MSSS, INSPQ and Ouranos are addressing these areas on a regional scale in Quebec. This section provides an overview of the efforts that are starting or underway to prevent or mitigate the negative health effects associated with climate change.

6.3.2 Methodology

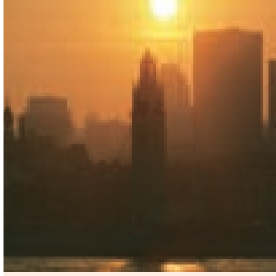
Literature review and semi-structured telephone interviews provided the information on current adaptation initiatives in each of the six targeted areas. The literature review (of scientific and government documents) was conducted using general (Google) and specialized (e.g. Medline, Web of Science) search engines, and from sources published either in French or English between 1995 and 2005 that were applicable to Quebec. Semi-structured telephone interviews, averaging approximately 15 minutes each, were conducted with key informants from public and private institutions (e.g. health care, occupational health and safety, air quality protection, urban climates, land management and environmental measures, air conditioning technology, environmental law and public safety). These key informants were from the 15 administrative regions in southern Quebec; the northern regions are addressed in Chapter 7, Health Impacts of Climate Change in Canada's North.

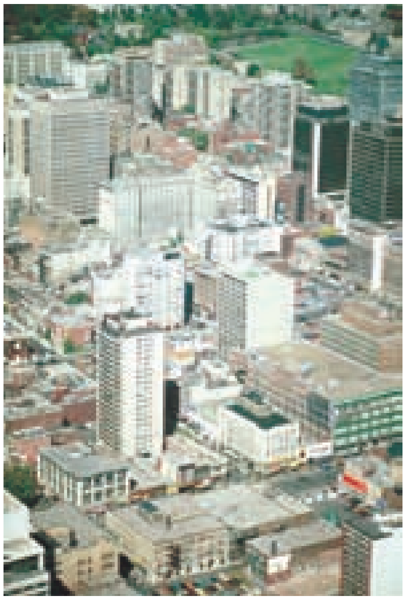
The initiatives identified for the period 2004–07 were assessed by comparing them with Canadian, American or international recommendations from various organizations such as the Government of France, U.S. Environmental Protection Agency (USEPA), U.S. Centers for Disease Control, the World Meteorological Organization, the World Health Organization and Health Canada. Emphasis was on the following subjects: heat waves and urban heat islands; preparation for ECEs; water and food; and vector-borne and zoonotic diseases. National and international health recommendations were compared with current adaptation initiatives in Quebec to address issues related to the various themes studied, and a synthesis of the required adaptations was prepared. The results of these overviews were recently published (Giguère and Gosselin, 2006a, 2006b, 2006c, 2006d). Two other areas, UV rays and air pollution, have not yet been investigated in depth because of limited available resources. The relationship between air quality and climate change in Canada is reviewed in Chapter 4, Air Quality, Climate Change and Health.

6.3.3 Heat Waves and Urban Heat Islands

6.3.3.1 Context

In southern Quebec, global climate models predict that by the end of the century, average temperatures will increase by an additional 2 to 3°C in the summer (Ouranos, 2004). This would likely be accompanied by an increase in the frequency and intensity of heat waves (Warren et al., 2004). The definition of a heat wave varies a great deal from one location to another (Institut de veille sanitaire (InVS), 2003b). For Quebec, a heat wave warning is currently issued when the Environment Canada forecast for a period indicates



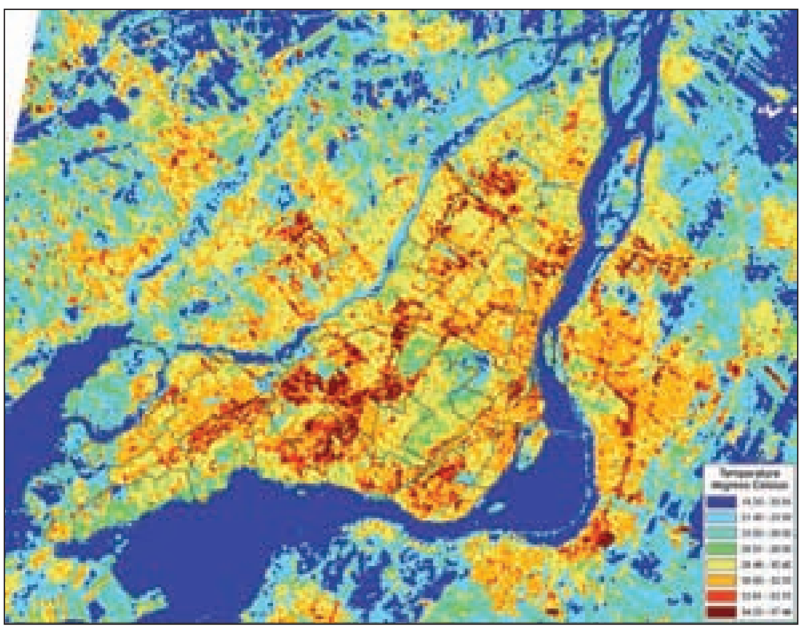


no less than three consecutive days during which daytime outdoor air temperatures are greater than 33°C and the minimum nighttime temperatures are 20°C or greater, or two nights during which the temperature remains at 25°C or more (Direction de santé publique (DSP) de Montréal, 2004, 2006).

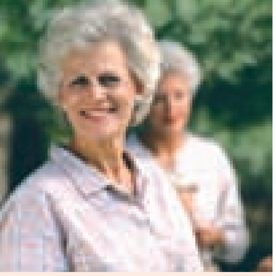
The urban heat island effect (UHIE) is generated by asphalt surfaces and various infrastructure materials that absorb heat, thereby increasing the outdoor air temperature by 0.5 to 5.6°C (Oke, 1982) (Figure 6.3). This phenomenon affects a significant proportion of the population, especially socio-economically disadvantaged individuals living in urban areas and people with chronic illnesses or cardio-respiratory diseases (including children and seniors) (Patz et al., 2000; Michelozzi et al., 2005; Haines et al., 2006).

A general provincial plan is not in place for adaptation measures to address heat waves and UHIEs. However, MSSS has stipulated that, for 2007, public health units in the seven socio-health regions in southern Quebec are to include specific intervention strategies for periods of extreme heat in their emergency measures plans (MSSS, 2006a). Initiatives also include various brochures and training programs related to the risk of heat waves to the general population and certain vulnerable groups, such as seniors or certain groups of workers (Commision de la santé et de la sécurité du travail (CSST), 2004; MSSS, 2004).

Figure 6.3 Example of heat islands in the Montreal region, summer 2001



Source: Courtesy of F. Guay, Ouranos Consortium.



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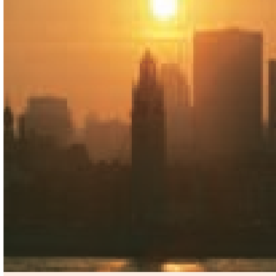
6.3.3.2 Current adaptations

In 2004–05, heat wave warning systems were prepared for nine cities with more than 100,000 inhabitants. As yet, none of the cities has had to deal with a long-lasting heat wave. However, some of the initial steps before a full alert have been successfully implemented in real-life situations. A simulation in Montreal (Health Canada, 2005) also identified some improvements that could be made to existing plans. In addition, Ouranos is currently planning or conducting research projects on heat waves and UHIEs (Table 6.1).

Table 6.1 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.

Various initiatives (using pamphlets and other communication tools to address the risks associated with extreme heat) have been put in place to inform the general public and some of the more vulnerable clients, such as seniors and their families, and certain groups of workers. A similar awareness-raising initiative was undertaken with health institutions and other groups (e.g. CSST, Réseau public québécois de la santé au travail (Quebec public occupational health network) and organizations (e.g. medical clinics, pharmacies, Fédération des locataires d'habitations à loyer modique (federation of low-cost housing tenants). A recent exploratory study in the Estrie region on medication use during periods of oppressive heat illustrates the importance of cautions by pharmacists (Albert et al., 2006). A significant percentage (30.2%) of people aged 65 and over take a type



of prescription medication whose absorption can be affected by dehydration, or that can impede caloric loss or alter kidney function. Nearly 5% of seniors were taking three or more medications of this type at the same time.

Several municipalities (e.g. Quebec, Gatineau, Montreal, Laval, Saint-Eustache) are increasing tree plantings along streets, improving tree maintenance and making their replacement mandatory. Province-wide standardization of fines for cutting down trees should contribute to their conservation (Government of Quebec, 2005a). The increasing interest in green roof systems and high-albedo roofs[3] that lower the absorption of solar energy, and increasing use and availability of public transportation in some regions help to reduce the UHIE (Ducas, 2004; Ville de Montréal, 2005).

6.3.3.3 Required adaptations

In light of literature reviews and semi-structured telephone interviews (Giguère and Gosselin, 2006d), the following could be developed in Quebec to decrease the negative effects of heat waves and urban heat islands, according to the authors:

- increased training for health professionals;
- popular education pilot projects on personal protection during heat waves and on helping to combat the UHIE;
- economic measures to encourage the implementation of various initiatives to mitigate the effects of heat waves, specifically measures related to better residential insulation;
- improvement of knowledge related to aeration, ventilation and air conditioning for health and long-term care centres;
- new guidelines for the management of health care centres during heat waves; and
- ongoing reinforcement of initiatives that have already been implemented, specifically those addressing real-time monitoring of the effects of heat waves.

A record of existing air conditioning in hospitals and long-term care centres is suggested to ensure knowledge of the resources, target where improvements can be made, and complete the information being collected for current extreme-heat research projects. MSSS is currently implementing such a system. Regulations on energy efficiency in buildings date back to 1983, and are currently being re-evaluated by the government.

6.3.3.4 Synthesis

Current heat wave adaptation efforts appear fragmented. However, although certain key preventative measures are lacking, ongoing and completed research projects (Table 6.2), legislation, heat wave-related emergency plans and surveillance measures represent a very good start for the implementation of adaptation measures. Preventative measures, notably to combat the effects of urban heat islands and to improve the energy efficiency of homes and institutions, in addition to the commitment to increasing air conditioning in care facilities (Government of Quebec, 2006e), are to be implemented, likely in the coming years. To date, the initiatives represent a balanced portfolio of short-term measures as well as long-term preventative ones.

3 High-albedo roofs reflect most of the solar energy away from their surface before it is absorbed and converted into heat energy.

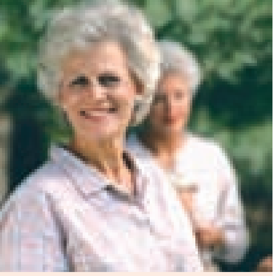


Table 6.2 Other ongoing or completed (C) health projects in Quebec except for northern regions (2002–2008)

Theme	Title
Heat Waves and Climate Warming	1. Awareness of risks encountered by outpatients suffering from chronic pulmonary disease and measures to be taken during periods of intense heat (2008) 2. Historic variability analysis of general mortality (in relation to temperature) and simulations for 2020, 2050 and 2080 with downscaling (C) 3. Survey of personal and family perceptions, vulnerabilities and adaptations (C)
Air Quality	4. Increase in concentrations of organic particulate (pollen) caused by climate change and potential consequence for respiratory disease and vulnerable populations in urban environments (Climate Change Action Fund) (C)
Vector-Borne and Zoonotic Diseases	5. Geosimulation of the progression of West Nile virus infection as a function of climate in Quebec (2007)
Climate Change and Adaptations	6. Survey of health and municipal managers on perceptions, vulnerabilities and adaptations (includes extreme climatic events) (C) 7. Post mortem on adaptations to disasters and catastrophes (including extreme climatic events), for the period between 2004 and 2007 (C) 8. Post mortem on adaptations to vector-borne diseases in Quebec, for the period between 2004 and 2007 (C) 9. Post mortem on adaptations to heat waves and urban heat islands in Quebec, for the period between 2004 and 2007 (C)

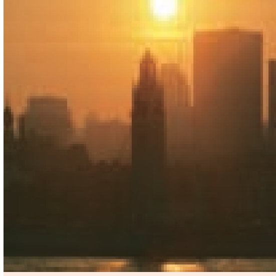
Note: (C) indicates completed projects.

6.3.4 Emergency and Extreme Climate Event Preparedness

6.3.4.1 Context

In Quebec, as elsewhere in the world, climate scenarios predict an increased frequency and intensity of certain ECEs including hurricanes, heat waves and heavy rainfall causing floods (Ouranos, 2004). The ice storm that hit the Montreal region in 1998 was a turning point in Quebec's awareness of civil protection; in 2001, the *Civil Protection Act* reorganized the civil protection system (MSP, 2005).

The consequences of ECEs include damage to physical structures and individuals (both the people who are affected and those who work with them) who experience short- and long-term physical and psychological effects (Maltais et al., 2001a, 2001b; Auger et al., 2003). Displacement of affected populations, the gravity of health effects, insurance coverage and material losses may all lead to psychological sequelae.



6.3.4.2 Current adaptations

Recent changes to provincial legislation have improved civil protection (MSP, 2005) and the linkages among stakeholders appear to have improved. Most of the adaptation initiatives have their roots in the surveillance and monitoring, training and education, and regulation and policy sectors. A storm and flood detection system and real-time surveillance of dams and rivers is in place for the entire province. A new, standardized approach to risk analysis and management in municipalities for 19 risks is being implemented, and is complete for two risks: forest fires (natural) and fires (human-induced) (Table 6.3). The involvement of public health branches, MSSS and INSPQ is planned as part of the implementation of emergency plans and measures. Land use plans for cities and regions intend to include climate change considerations that are consistent with provincial regulations (flood plain management) and advice from public health branches, and MSSS will provide feedback on development plans and urban planning. Ouranos will be undertaking a research project on the ECEs (Table 6.1) that involves assessing the feasibility of developing real- and non-real-time surveillance tools for the health effects of these events.

Table 6.3 Types of natural or human-induced risks that will be included in risk analysis in Quebec municipalities

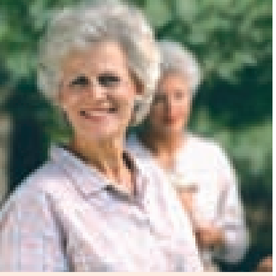
Risks	
Natural	***Human-induced***
Avalanches	Social disruption
Meteor showers	Buildings and structures collapse
Epidemics, pandemics, infestations	Major fires and conflagrations
Forest fires	Failure, shortages and contamination of goods and services
Floods	Industrial risk
Landslides	Nuclear and radioactive risks
Storm surges	Dam failure
Extreme weather phenomena	Terrorism
Earthquakes	Hazardous material transportation accident
	Accident when transporting people and merchandise

Source: MSP, 2004.

6.3.4.3 Required adaptations

Based on the summary of the adaptations recommended by the various agencies that were consulted, the authors of this study concluded that Quebec should further develop prevention programs or invest in programs to address ECEs (Giguère and Gosselin, 2006b). Investments have increased over the past 10 years, but they have recently declined. The following initiatives for adaptation to ECEs in the context of climate change are encouraged:

- improvement of planning and preventative investment for ECEs, such as the protection of buildings and critical infrastructure (e.g. power supplies, specifically for heating and food storage), and water treatment facilities;
- measurement, modelling and the communication of risks for the various types of ECEs over the short-, medium- and long-term to develop appropriate initiatives;



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- research on the short- and long-term effects of ECEs on health and the improvement of emergency health measures; and
- implementation of a system for the surveillance and epidemiological follow-up of health effects (deaths, injuries, infectious diseases, psychosocial effects) of ECEs.

6.3.4.4 Synthesis

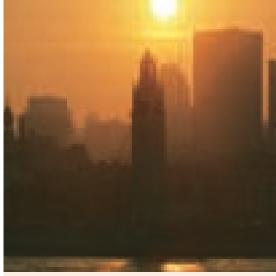
Quebec has one of the most advanced health surveillance and environmental monitoring systems in Canada, as well as a good emergency response system according to the study led by Giguère and Gosselin (2006b). However, none of these health surveillance systems specifically addresses ECEs, a gap the authors recommend to correct. Disaster and ECE adaptation initiatives should be developed by adding a component relating to the effects of climate change, as well as a significant component relating to the prevention of impacts on health. The risk analysis approach used by civil protection stakeholders (implementation is beginning) will play an important role in achieving this. These suggestions have been integrated into the 2006–2012 action plan of the Quebec government (Government of Quebec, 2006e).

6.3.5 Water

6.3.5.1 Context

The current abundance of water resources is reflected in the 326-litre average per capita daily water consumption (Center for Research and Information on Canada (CRIC), n.d.) and the many private swimming pools in Quebec (50% of pools for 23% of the population). The projected effects of climate change include the drop in levels, flow and quality of watercourses; changes in the rainfall regime; and an increase in the salinity of the St. Lawrence River (Environment Canada, 2005b). These changes will have a significant impact because surface water is the source of drinking water for more than 70% of Quebeckers (MDDEP, 2002a). The quality and quantity of current abundant water resources could be compromised. The possible impacts are substantial and briefly described here.

Water-borne diseases can occur when pathogenic microorganisms migrate to underground or surface water sources (Canadian Council of Ministers of the Environment (CCME), 2004, 2005). Phosphorus, nitrogen, sunlight and heat are the primary factors associated with the formation of cyanobacterial water blooms (Magnuson et al., 1997; Giani et al., 2005; Rolland et al., 2005). In Quebec, this phenomenon was reported in 84 lakes and streams between 1999 and 2003 (INSPQ, 2006c), and led to bans on consuming and bathing in the water from these sources, although no cases of human disease have been reported to date. The cyanotoxins produced by cyanobacteria can cause skin irritation, as well as severe liver and nerve damage when contaminated water comes into contact with skin or is ingested (American Water Works Association, 1999; Agriculture and Agri-Food Canada, 2003). Young children, seniors and people with chronic diseases are at higher risk of developing severe symptoms from contaminated water. People who are engaged in water sports are also particularly vulnerable to natural biotoxin contamination (Agence de développement de réseaux locaux de services de santé et de services sociaux, 2003; MDDEP, 2005a). The larger population could be affected both physically and psychologically by water shortages, and families at risk could experience a higher degree of food insecurity if they were required to purchase their water (DSP de la Montérégie, 2004).



6.3.5.2 Current adaptations

Water quality surveillance is generally well organized by MDDEP and the St. Lawrence Centre. Training for regional public health branches on water issues is excellent, and abundant information is available to the public and professionals. Several environmental initiatives to decrease contaminants are underway in cities and industry, including the forestry and agricultural sectors. The recent changes made to water quality (MDDEP, 2005b) and pesticide legislation should have a beneficial effect on water quality by decreasing surface runoff waste.

Surveillance of illness outbreaks associated with water and food is not well developed among the general population but is better established in institutional and commercial settings. Ouranos is planning public health research projects on water quality (Table 6.1).

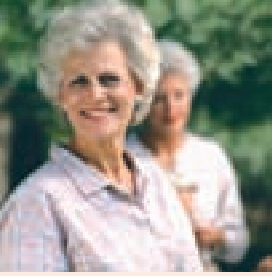
6.3.5.3 Required adaptations

Comparison of existing adaptations with those recommended (Giguère and Gosselin, 2006a) indicates the following should be developed or more widely applied throughout the province:

- accelerated implementation of various methods for maintaining optimal water quantities to ensure the safety of persons (fire, basic hygiene, food requirements) and quality drinking water (pressure, dilution). These include specifically:
  - optimization and standardization of leak detection for water supply systems
  - education of individuals and businesses about the importance of and methods for conserving drinking water
  - inclusion of low water use techniques in the *Building Code*;
- strict control of water quality surveillance in small drinking water supply systems;
- financial support to implement watershed management, to accelerate implementation and preserve multiple uses;
- development of management policies for cases of conflict over supply; and
- improved epidemiological surveillance of health impacts related to drinking water and recreational water to ensure faster and more sensitive detection of outbreaks by public health authorities.

6.3.5.4 Synthesis

Climate change will likely have a major negative impact on the quality and quantity of water resources in Quebec due to more frequent and severe low-flow and drought periods, as well as diminished flow from Lake Ontario (into the St. Lawrence) and the Ottawa River (Environment Canada, 2002; Croley, 2003; Fagherazzi et al., 2005). Because these sources provide drinking water for the Greater Montreal area, major difficulties in water use management are expected (Vescovi, 2003). Water quality also seems to be affected by climate change, and abundant rainfalls have been associated with increased rates of gastroenteritis in recent studies from the U.S. (Curriero et al., 2001) and Canada (Thomas et al., 2006). The legislative frameworks for drinking water quality, watershed management, and pesticide management are basic tools for adapting to climate change, and have recently been updated significantly. Their implementation has begun, and water resource management practices and water treatment infrastructures should be better coordinated because currently several controversial files affect land management and public health.



Chapter 6

6.3.6 Vector-Borne and Zoonotic Diseases

6.3.6.1 Context

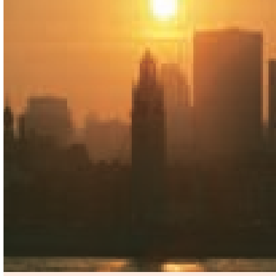
In Quebec, the trend toward warmer temperatures (which has been observed and predicted by climatic scenarios) could encourage the appearance of vector-borne and zoonotic diseases that do not normally occur here, or could increase the range for some diseases currently present. According to models, Lyme disease is expected to appear in southern Quebec within 10 to 20 years (Ogden et al., 2006) (Figure 6.4). Climate influences several aspects of infectious disease cycles, such as the reproduction of animals, insects and ticks; the ease with which insect vectors can transmit the disease; and human behaviour leading to exposure to various vectors (Ontario Forest Research Institute, 2003). Other than the West Nile virus, there are currently no other significant cases of vector-borne diseases; only one isolated case of hantavirus has been reported to this point (Giguère and Gosselin, 2006c).

Figure 6.4 Simulation of changes in the range for Lyme disease, toward 2050

Source: Ogden et al., 2006.

6.3.6.2 Current adaptations

Surveillance of zoonotic and vector-borne diseases is well organized by the various departments involved, in part because the public system subsidizes a portion of the research. Certain diseases require mandatory reporting; this measure helps to limit outbreaks. The Public Health Agency of Canada and MSSS make information about infectious diseases available to the public and professionals. Public health branches distribute pamphlets and provide information on Internet sites to keep the public informed about current infectious diseases. The *Laboratoire de santé publique* (public health laboratory) is very well organized and provides excellent support for any analyses that are required.



West Nile virus was the most closely monitored disease until recently (Gosselin et al., 2005), as sampling campaigns and larvicide control measures ended in 2006. Several research projects have been completed or are underway (Table 6.2). A decision-support tool is being designed for West Nile virus, based on the geosimulation approach and including the climate change context (Bouden et al., 2005). Several very effective zoonotic surveillance networks have been established by the *Ministère de l'Agriculture, des Pêcheries et de l'Alimentation* (MAPAQ) (department of agriculture, fisheries and food) (MAPAQ, 2006) and the *Institut national de santé animale* (national animal health institute). Since 1997, they have regularly collaborated with MSSS and the public health branches on epidemiological research. MAPAQ has also invested heavily in research and laboratories over the last few years (MAPAQ, 2006).

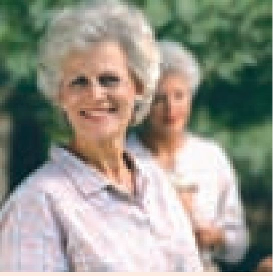
6.3.6.3 Required adaptations

Experts consulted in the Giguère and Gosselin study (2006c) outlined several important steps for improved adaptation to the emergence and increase of zoonotic and vector-borne diseases related to the effects of climate change in Quebec:

- maintain, encourage and implement integrated surveillance systems for zoonotic and vector-borne diseases that may present new risks with climate change;
- include indicators related to the effects of climate change—such as consideration of the epidemiological and ecological changes related to these diseases—in surveillance systems for zoonotic and vector-borne diseases;
- heighten awareness and education initiatives for individuals, farmers, and human and animal health professionals to address emergence, intensification, detection and protection issues as they relate to zoonotic and vector-borne diseases in the context of climate change; and
- continue research into methods for the control of zoonotic and vector-borne diseases; specifically, the implementation of preventative technologies to prevent natural and artificial aquifers from becoming suitable mosquito breeding areas and the inclusion of these technologies in infrastructure construction standards.

6.3.6.4 Synthesis

Considering the several climate change adaptation initiatives underway in this area of public health, it is the area that offers the most extensive coverage of the population. However, Giguère and Gosselin (2006c) note that Quebec has been spared to a great extent from vector-borne health risks until now. In the future, climate change will likely increase the importance of vector-borne diseases in the province. 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. The importance of food safety in a context of commercial agricultural production has helped to stimulate various adaptation initiatives that are also related to reducing risks associated with vector-borne and zoonotic diseases; the significance accorded to these initiatives by the health sector has increased. However, difficulties exist, such as how to effectively reach the thousands of farmers scattered across the province and how to deal with millions of potential mosquito breeding grounds. Existing vector-borne and zoonotic surveillance systems have not yet been tested in a large scale event in such a way as to demonstrate their capacity to handle a major epidemiological situation affecting humans.



6.3.7 Other Subjects

6.3.7.1 Ultraviolet rays (UV)

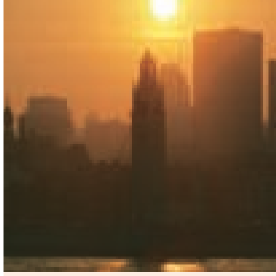
With climate change, it is expected that the warm season will be extended, and public exposure to UV rays will increase (Hill et al., 1992).

The incidence of health problems associated with over-exposure to UV rays, particularly sunburns and skin cancer, could continue to increase at a greater rate than in previous decades. An increase in the number of cataracts can be expected, as well as an immunosuppressant effect that could, for example, have a negative effect on vaccine effectiveness and foster the development of epidemics (WHO, 2003). Despite this fact, there has been very little research into climate change and public exposure to UV rays in Quebec. Furthermore, UV protection is rarely considered in proposed climate change adaptation measures in Quebec despite its priority nationally (Warren et al., 2004). The effects on public health are serious, with more than 80,000 new cases of skin cancer in Canada each year. This is the most common type of cancer (Canadian Cancer Society, 2005). The health effects associated with UV rays are preventable with modified personal protection behaviours and with the creation of shade. Moreover, UV risk-awareness programs are cost effective. For example, in Australia, the prevention of the negative effects of UV rays costs an average of eight cents (US) per capita whereas cancer treatment costs $5.70 (US) per capita (WHO, 2003).

Tools currently available include the UV index issued by Environment Canada, which is widely available to the public. In addition, the National Sun Safety Committee brings together scientists from every Canadian province to encourage cooperation and intersectoral action in reducing the incidence of UV-caused skin cancer (Canadian Strategy for Cancer Control, 2001). Required adaptation measures include increased educational programs about the dangers of UV exposure, research projects to measure the effects of climate change on population behaviour in terms of UV exposure, and measuring the effectiveness of the various adaptation measures designed to decrease UV exposure. Preventative measures for shade creation will also be useful.

6.3.7.2 Air quality

In addition to producing carbon dioxide (CO_2), the burning of fossil fuels affects air quality. Various pollutants and tropospheric ozone precursors, as well as the fine particulates involved in the production of urban smog, have been proven responsible for harmful health effects. More than 80.4% of Quebeckers live in urban areas, and 25% of them live in the Montreal area (ISQ, 2006e, 2006f), which is already greatly affected by poor air quality (ISQ, 2006e, 2006f; INSPQ, 2006c). Climate change will also increase the time periods conducive to smog formation (Warren et al., 2004). Further, climatic warming will have an additional negative impact on air quality because there will be longer growing seasons, causing an increase in concentrations of airborne pollens (Warren et al., 2004; House and Brovkin, 2005).



Climate models predict an increase in the frequency of ECEs, including droughts, wildfires and storms (increased pollen dispersion is among the associated effects), all of which have a negative impact on air quality (Warren et al., 2004; U.K. Department for Environment, Food and Rural Affairs (DEFRA), 2005). In Montreal, links have been established between climate and pollen concentrations, as well as among pollen concentration, visits to the doctor and socio-economic status (Garneau et al., 2005). Poor air quality is responsible for premature deaths among vulnerable populations, such as individuals with respiratory disease, allergies or cardiac disease, in particular children and seniors. The effects of pollen can compound this and are significant in terms of health effects and costs, given the existing high rate of allergies. It is estimated that 10% of the population suffers from respiratory diseases and allergies (Agence de la santé et des services sociaux de la Montérégie (ASSSM), 2002); in Quebec in 1992, the annual direct cost of hay fever amounted to $49 million.

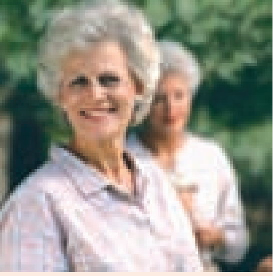
This area of concern is the subject of current research projects (Table 6.1) as well as one recently completed project (Table 6.2). Existing adaptations in place include air quality indices (e.g. InfoSmog) available throughout the year (Environment Canada, 2006b), but their usefulness appears minimal according to recent studies (Bélanger et al., 2006a; Tardif et al., 2006) and they will likely need to be enhanced. The required adaptations include preventative measures to encourage decreased activities during periods of high air pollution, and the promotion of measures to improve air quality, such as using public transportation, travel by bicycle or on foot, and the purchase of smaller vehicles that consume less energy and raw materials to manufacture and operate. Further information and data on the relation between air quality and health should be considered a priority, given the burden that poor air quality imposes on health.

6.3.7.3 Strategic communication and research tools

Climate change adaptation efforts should be conducted in a concerted manner, based on reliable and accessible data, to respond effectively to new demands and to involve all stakeholders. Current initiatives include an atlas of health vulnerabilities, and projects under the Ouranos health program (Table 6.1) and the INSPQ Infocentre (INSPQ, 2006b). However, a permanent knowledge-based distribution and transfer program to address climate change adaptations has yet to be developed and implemented. This program would be intersectoral, given the wide range of adaptations and the various stakeholders involved. This activity is included under the Ouranos health program outlined in Table 6.1.

6.3.8 Synthesis

Currently, several climate change adaptation initiatives are being implemented—a positive indication for the province. These include an integrated and planned research and surveillance effort that addresses the connection between health status and climate; and certain products are being distributed to managers in various provincial departments and the regions and used for policy formulation and program development. The recent implementation of several significant legislative and regulatory tools to protect public health and to implement preventative measures is also a positive element in the context of adaptation to climate change. The excellent history of interministerial and intersectoral cooperation in Quebec will be a considerable asset in the highly complex domain of adaptation. But as yet, there is no integrated public health program that could launch a coordinated charge on the priorities in this area and address the gaps that have been identified (Bélanger et al., 2006a).



Chapter 6

In light of the research conducted and experts who were consulted (Giguère and Gosselin, 2006a, 2006b, 2006c, 2006d), the following initiatives in the areas listed here should be developed.

For extreme heat:

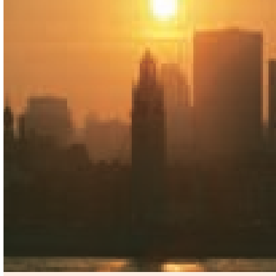
- training for health professionals;
- implementation of popular education pilot projects on personal protection during heat waves and on contributing to controlling the UHIE;
- addition of economic measures to encourage the implementation of initiatives to mitigate extreme heat phenomena, specifically measures related to better housing insulation;
- improvement of knowledge about aeration, ventilation and air conditioning for health care centres and nursing homes;
- new guidelines for the management of health care centres; and
- ongoing reinforcement of initiatives that have already been implemented, particularly with respect to real-time surveillance of the effects of heat waves.

For adapting to ECEs in the context of climate change:

- promotion of a culture of preventative planning for ECEs, such as building protection, critical infrastructure (e.g. transportation, power supply, water treatment plants);
- measurement, modelling and communication of risks of the various types of ECEs in Quebec over the short, medium, and long terms to develop the appropriate initiatives;
- research on the effects of ECEs on health over the short and long terms, in addition to the improvement of emergency health measures; and
- implementation of a surveillance and follow-up system on health effects of ECEs as a function of the climate.

For water resources:

- accelerated implementation of the various methods for the maintenance of optimal water quality to ensure human safety (fire, basic hygiene, food needs) and drinking water quality (pressure, dilution). These include:
  - optimizing and standardizing leak detection in water supply systems
  - educating individuals and businesses on the importance and means of conserving drinking water
  - integrating low-water use techniques into the *Building Code*;
- strict control of water quality surveillance in small drinking water supply networks;



- financial support for watershed management and infrastructure to accelerate its implementation and preserve the multiple uses of the watershed;
- development of management policies for conflicts over supply; and
- improvement of surveillance of health effects related to drinking and recreational water.

For zoonotic and vector-borne diseases:

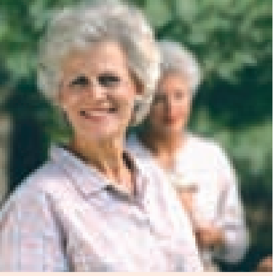
- implementation and maintenance of integrated surveillance systems for zoonotic and vector-borne diseases that may present new risks with climate change;
- inclusion of indicators related to the effects of climate change—such as consideration of the epidemiological and ecological changes related to these diseases—in surveillance systems for zoonotic and vector-borne diseases;
- intensified awareness and education initiatives for individuals and human and animal health professionals that address emergence, intensification, detection and protection issues as they relate to zoonotic and vector-borne diseases in the context of climate change; and
- continuation of research into methods for the control of zoonotic and vector-borne diseases, specifically the implementation of preventative technologies to prevent natural and artificial aquifers from becoming suitable breeding areas for mosquitoes, and on the inclusion of these technologies in infrastructure construction standards.

For protection against increased exposure to UV rays:

- increase in the visibility of educational programs on the dangers of UV exposure and on effective prevention measures;
- research projects to measure the effects of climate change on population habits in terms of UV exposure and measurement of the effectiveness of the various adaptation measures designed to decrease UV exposure; and
- creation of more shade in urban environments.

For air quality:

- assessment of the usefulness of air quality indices for behavioural changes related to preventative and protective measures;
- implementation of measures to improve air quality, such as the promotion of public transportation, travel by bicycle or on foot, and purchase of smaller, cleaner vehicles; and
- maintenance and development of available knowledge and new data on air quality and health.



6.4 HISTORICAL AND SIMULATED MODELLING OF MORTALITY FOR 2020, 2050 AND 2080

6.4.1 Introduction

In Canada, as in many other countries, climatic warming means an increase in average temperatures and a rise in sea level, as well as a greater probability of ECEs (e.g. periods of intense heat, freezing rain, floods) (Natural Resources Canada (NRCan), 2002). This situation is recognized as a public health concern (WHO, 2000, 2002; Donaldson et al., 2001) because of the effects of climate change on increased mortality and morbidity related to heat stroke, skin cancers, cardiovascular and respiratory diseases (e.g. asthma), vector-borne and zoonotic diseases, kidney disease, liver disease, neurological disease (e.g. epilepsy) and mood disorders (e.g. depression) (McGeehin and Mirabelli, 2001).

Some of the research undertaken for this chapter was to identify and simulate certain future climate-related health effects in Quebec. The first goal was to quantify the relationships among mortality, some morbidities and climate. The second goal was to project future rates of mortality and hospitalization for a given future Quebec climate. Analyses were carried out using mortality (1981–1999) and morbidity data (number of hospitalizations, individuals hospitalized or emergency room visits between 1981 and 2002) in tandem with chronological series on several climatic parameters (e.g. temperature, diurnal range, Humidex) to create statistical models. These models were then paired with regional projections for climatic variables generated by Ouranos to identify variations in mortality and morbidity for simulated future periods.

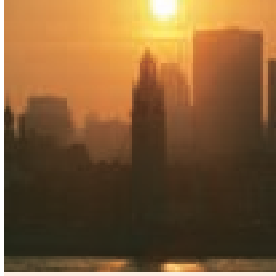
The first part of the results is presented here; this includes selected statistical mortality models for several cities and regions in Quebec, as well as projections associated with these models for three future periods (2020, 2050 and 2080 horizons). The other analyses on hospital morbidity and emergency room visits are underway and will become available in 2008. The main data sources used in this project are presented (under section 6.4.2 Methodology) along with a few details on data processing, as well as the creation of the database. The project methodology and results are then presented and discussed.

6.4.2 Methodology

Health data (deaths, hospitalizations, emergency room visits) are all from MSSS. Only non-traumatic deaths were included (codes 1 to 799 in the International Classification of Diseases (ICD-9)). Deaths for the period between 1981 and 1999 were used for the following two reasons:

- Beginning in 1981, death data were more reliable (before 1981 data were not exhaustive or not collected by area) and the format was easier to use; and
- Until 1999, cause of death was classified according to the ninth revision of the ICD (ICD-9) whereas beginning in 2000 the tenth revision (ICD-10) was used, making comparison more difficult.

Meteorological data were taken in part from Environment Canada airport weather stations. These stations collect by far the most complete data and include a large number of meteorological parameters. The airport station data sets were complemented by data from



other Environment Canada stations (Environment Canada, 2005a). While the latter are numerous, they produce only temperature and precipitation data. Each truncated postal code was associated with the closest meteorological station. Thus, mortality and morbidity models could be created as a function of the climate for quite a variety of areas. The climate average for a given geographic area was obtained by using all stations associated with the postal codes in this area.

Ouranos provided climate data for future periods. These included daily maximum, minimum and average temperatures for the 2020, 2050 and 2080 horizons. The data are from a specific general circulation model known as the HadCM (Hadley Centre coupled model) (Gordon et al., 2000) paired with scale-reduction techniques (or statistical scaling) (Nguyen et al., 2005). General circulation models are developed on a planetary scale and simulate, among other things, the effects of increases in GHGs for future periods. For this research, two specific emissions scenarios were considered: A2 and B2 (Nakicenovic et al., 2000). These scenarios were established by the Intergovernmental Panel on Climate Change (IPCC), and correspond to various worldwide changes in social, demographic, economic, technological and other domains. It should be noted that the A2 scenario is based on a higher concentration of GHGs (approximately twice the current levels in 2080) than the B2 scenario (IPCC, 2007). Scale-reduction methods make it possible to scale down the simulation results from global models to more local proportions (e.g. town, region). Historic data from weather stations are used to make this change in scale. In the present study, the percentage of explained variance for each predictor-predictand pair is equal to the same order of magnitude (between 65% and 90%) found in the study by Gachon et al. (2005). The predictands considered here are minimum, maximum and average daily temperatures. The various sensitivity analyses carried out to verify the accuracy of the climate models used have shown a high level of reliability—with the exception of the 2020 horizon period, which could be problematic because of the weakness of the expected changes and the lack of statistically significant climate signals (Gachon and Dibike, 2006).

Projections of mortality variations were assessed for certain cities and administrative regions in the province. All cities considered have a weather station close by; this makes it possible to reduce the scale. However, the size of the administrative regions may have reduced the accuracy of projections for these areas. Finally, there are several general circulation models, each of which produces a different version of future climates. The model used here (HadCM3) generates projections close to the average of the other models with the possible exception of winter, where temperature increase projections are below the average (Chaumont, 2005).

Identifying the effect of climate on mortality relies mainly on methods initially developed by Schwartz et al. (1996) for research on the effects of air pollution on health. Use of the Poisson regression made it possible to obtain a statistical relationship between the number of deaths per day and the various meteorological parameters available. More formally, this is a general linear model with specific link functions (McCullagh and Nelder, 1989). A parametric cubic spline function was chosen by the authors of this study (Doyon et al., 2006) to represent the link between deaths and a given climatic parameter. To obtain this relationship, one must control for confounding factors (effects of the day of the week, seasons, long-term mortality trends). As an example, Figure 6.5 presents the relationship between temperature and mortality for three cities in Quebec with and without controlling for confounding factors.

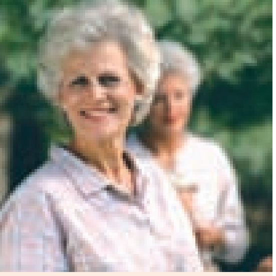
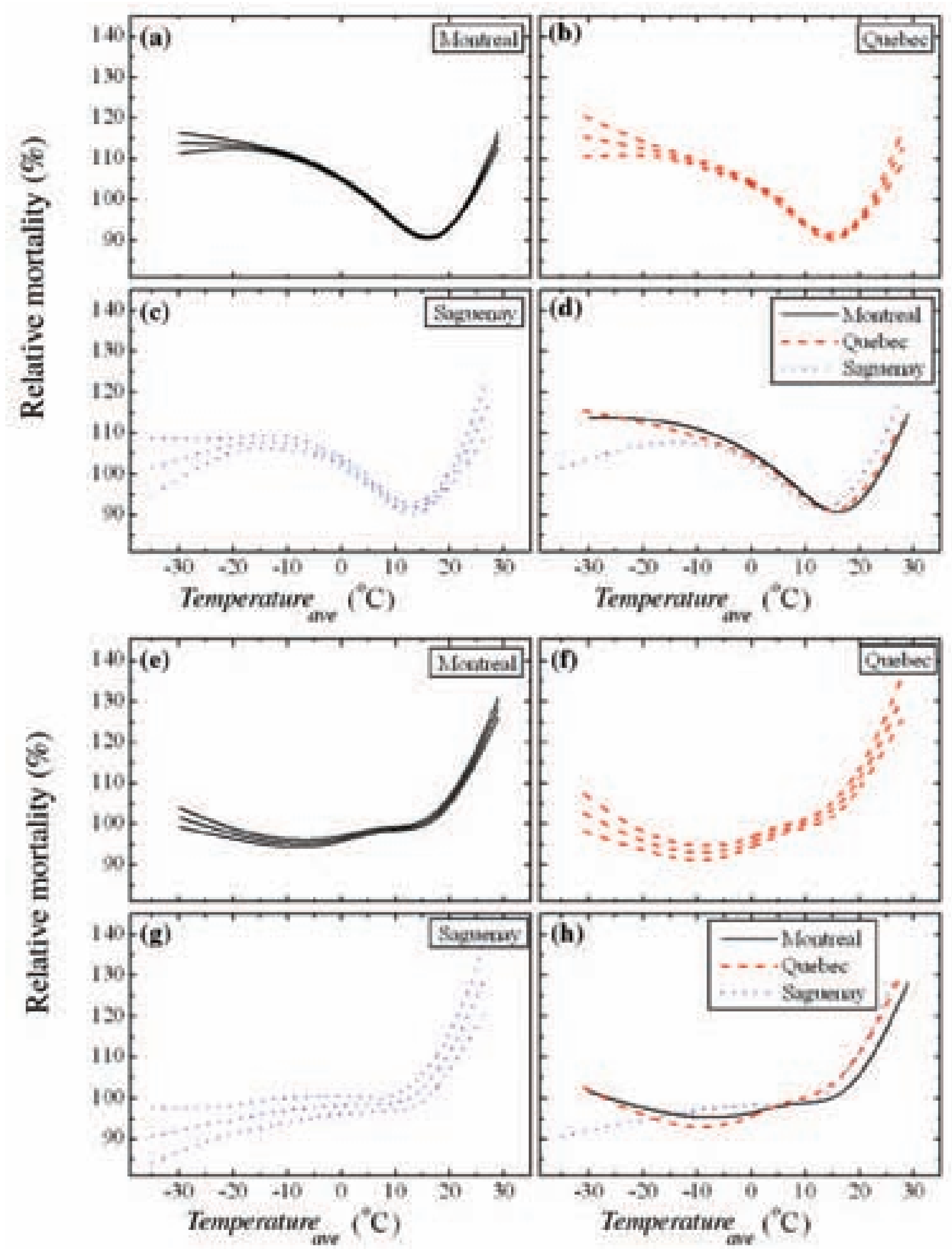
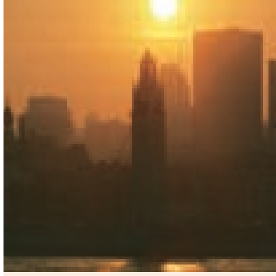


Figure 6.5 Relationship between mortality and average daily temperature for Montreal and Quebec City and the Saguenay Region



Note: Graphs (a), (b) and (c) are taken from the model in which confounding factors are disregarded. Graphs (e), (f) and (g) illustrate those taken from the model in which confounding factors are taken into consideration. Graphs (d) and (h) are overlays of (a), (b), (c) and (e), (f), (g), respectively.



Several meteorological parameters may be included in the mortality model. A first scan was conducted by adding the climatic variables available to the model, one by one. Preliminary analyses were conducted for several cities (Montreal, Quebec, Gatineau, Sherbrooke, Saguenay) for deaths due to all causes, and certain more specific classifications (death due to diseases of the circulatory or respiratory systems). Models have been built that consider various combinations of maximum, minimum and average temperatures and the Humidex. These analyses have made it possible to select only average temperature as the temperature indicator in the model. This variable stood out above others from a statistical point of view. The Akaike (1973) information criterion was used as a performance indicator. The addition of the diurnal range had practically no effect on the model. Nor did dew point, humidity or atmospheric pressure improve residual deviation from the model. Various groupings for time variables were then considered. Once again, the various groupings for time variables were added one by one. For example, the average temperature one to three days prior to death was added to the average temperature model. Another scan was then conducted on all climatic variables in addition to trying various time groupings on each scan. The final model that was selected contained groupings of average temperature up to 14 days prior to death.

This model was then paired with long-term climate simulations to estimate variations in future mortality. The results presented here do not include demographic forecasts; therefore, it is assumed that the size or population of a city or region will not change in the future. This is common practice for these types of simulations, and allows for comparison with the current situation. A detailed discussion of the methodology, sensitivity analyses and a presentation of the selected equations and terms, by city and region is found in Doyon et al., 2006.

6.4.3 Results

6.4.3.1 Historical modelling

One of the project goals was to provide a provincially scaled description of current and future climate effects on the population. First, daily mortality was assessed for several cities in southern Quebec. Statistics by administrative region were added to complement the numbers for cities for which modelling could be problematic; the methodology described in the preceding text may be problematic when death rates are low (<2 deaths/day). The low numbers also prevented modelling age and cause of disease for all cities and regions.

For an in-depth portrait of climate effects on the population, a relationship was established between climate and deaths from all non-traumatic causes for the cities and regions for which the models were significant. Only Montreal was selected for comparison of the effects of heat on causes of death. The causes chosen were deaths due to diseases of the circulatory system (ICD-9, codes 390–459), the respiratory system (ICD-9, codes 460–519) and tumours (ICD-9, codes 140–239).

Figures 6.5 and 6.6 demonstrate the relationship between mortality and average daily temperature for some cities and regions in Quebec. Note that the curves represent relative mortality as a function of temperature. For a specific temperature, the curves compare mortality to the average mortality for all other temperatures, taking into account the seasons, long-term trends and days of the week. (For example, 130% mortality at a given temperature indicates that there were 30% more deaths at this temperature than the average.)

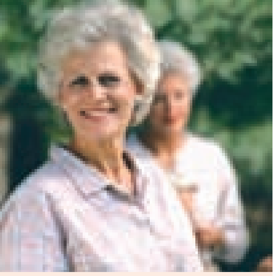


Figure 6.6 Relationship between mortality and average daily temperature for some regions in Quebec

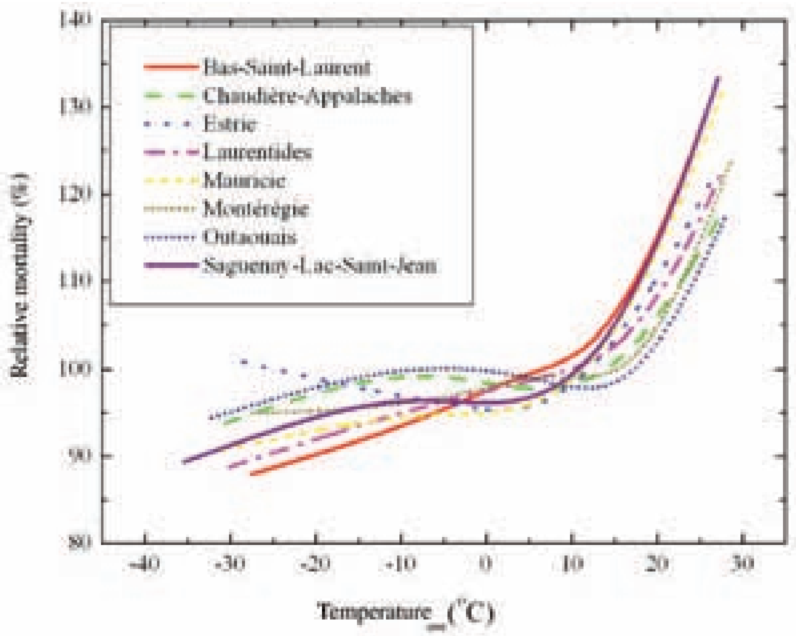


Figure 6.6 makes it possible, on a qualitative basis, to compare the effects of temperature on mortality for each region. The relationship with daily temperature was used because the latter is the climatic variable with the greatest effect on mortality. Generally, for all cities and regions, there seems to be a point beyond which the number of deaths increases almost linearly with temperature. In addition, the slope of the linear portion seems practically identical from one city or region to another. As for the effects of cold, no similar trends could be identified; the effects of cold seem to be more directly related to relative mortality as a function of temperatures in the weeks preceding death.[4]

Despite the size of the administrative regions and the different microclimates of those regions, the same quasi-linear relationship between mortality and temperature can be identified (for the "warm" part of the graph). For the Abitibi-Témiscamingue, North Shore, Lanaudière, Centre-du-Québec, Gaspésie-Îles-de-la Madeleine and Nord du Québec regions, no significant link between the temperature and the number of deaths seems apparent; consequently, these results are not presented. With the exception of Lanaudière and Centre-du-Québec, these regions are sparsely populated and are located in the northern and eastern parts of the province.

6.4.3.2 Estimating mortality for simulated future climates

The HadCM model with scenarios A2 and B2 was used for selected cities and regions to project the variation in mortality due to climate change for different periods. Figures 6.7 and 6.8 show projections for summer and annual mortality, respectively, for several cities. Figures 6.9 and 6.10 illustrate these projections for several administrative regions. Variations in mortality are expressed as a percentage of historic mortality (between 1981 and 1999) and presented for the future periods of 2020, 2050 and 2080. Projections for the summer seasons are presented because variations are most significant during this period. In general, there is a small drop in mortality in winter and a slight increase in spring and fall. Annual variations in mortality are also presented to provide information on a complete year. Because variations in summer mortality are much greater than in other seasons, there is an increase in annual mortality in a warmer future climate.

4 For example, see Figure 7 in Doyon et al. (2006).

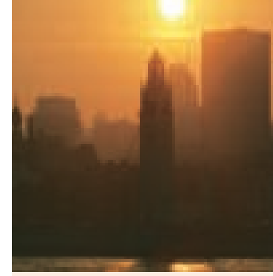
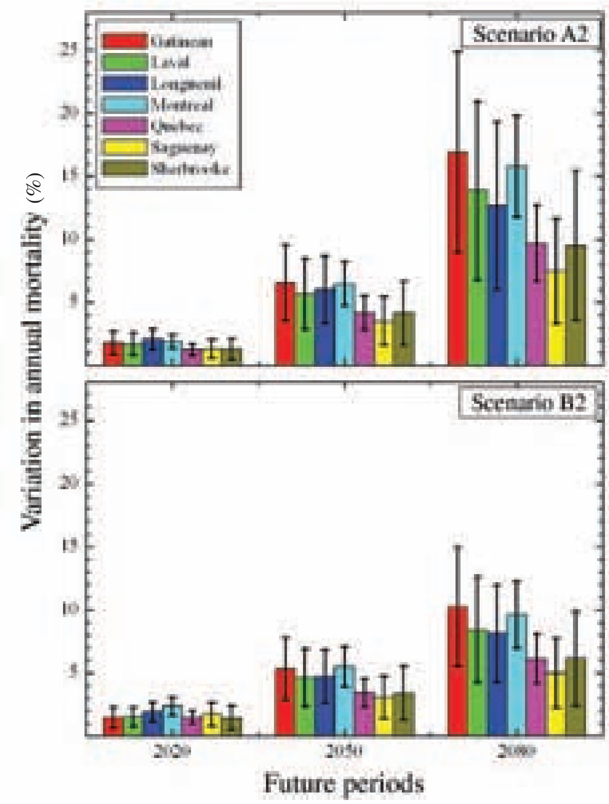
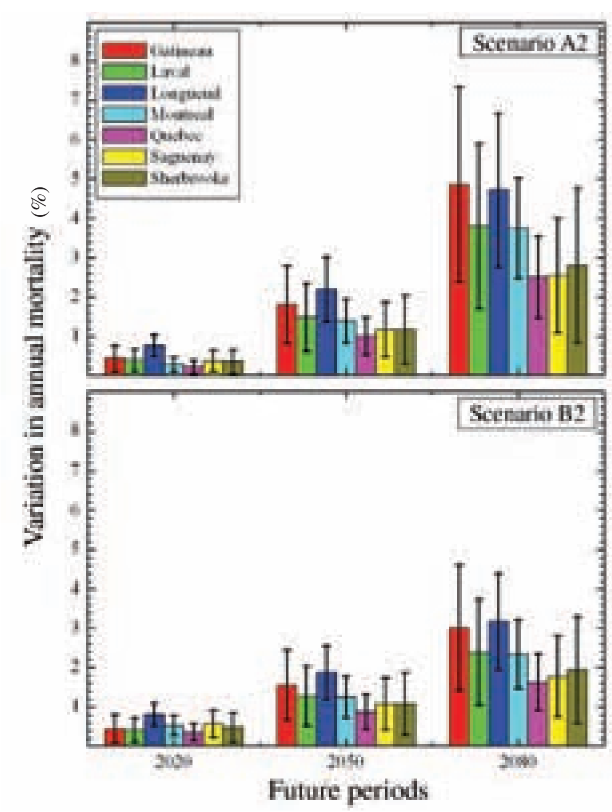


Figure 6.7 Variations in summer mortality for several cities in southern Quebec



Note: This figure presents expected variations in summer mortality in several cities in Quebec for scenarios A2 and B2. Variations are expressed as a percentage of historic mortality for the period from 1981 to 1999. Black error bars indicate the 95% confidence interval.

Figure 6.8 Variations in annual mortality for several cities in southern Quebec



Note: This figure presents expected variations in annual mortality in several cities in Quebec for scenarios A2 and B2. Variations are expressed as a percentage of historic mortality for the period from 1981 to 1999. Black error bars indicate the 95% confidence interval.

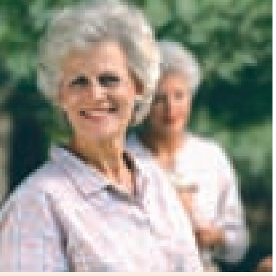
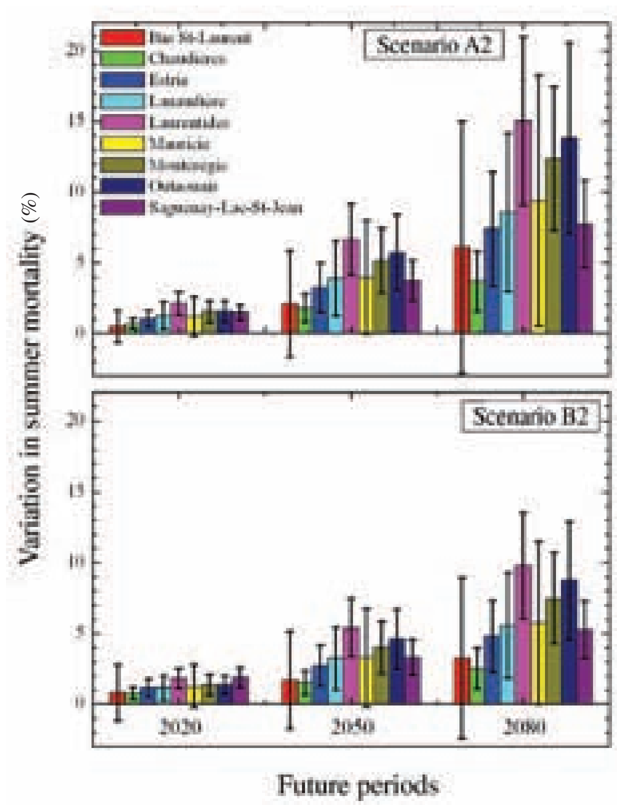
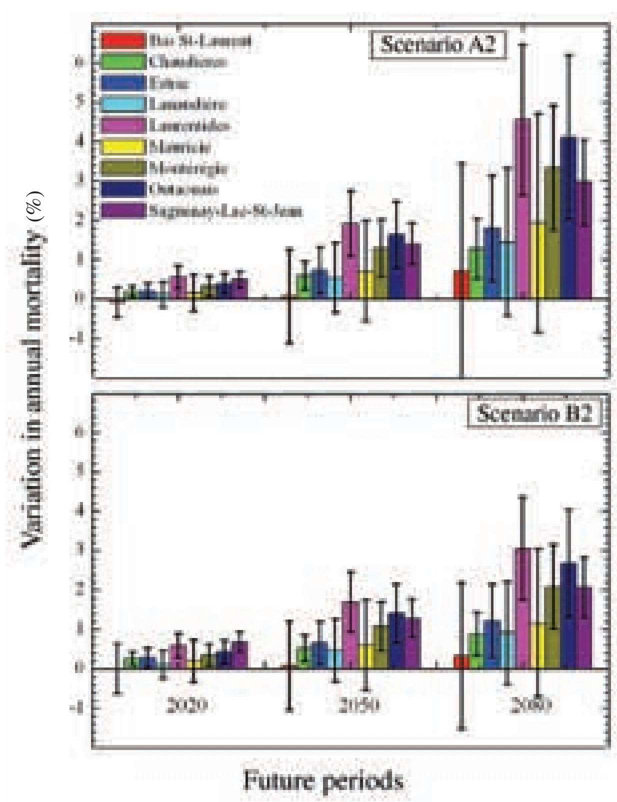


Figure 6.9 Variations in summer mortality for several regions in southern Quebec

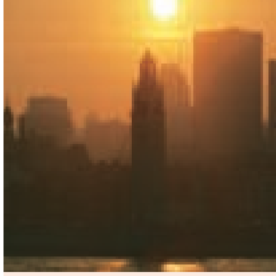


Note: This figure presents expected variations in summer mortality in several of Quebec's administrative regions for scenarios A2 and B2. Variations are expressed as a percentage of historic mortality for the period from 1981 to 1999. Black error bars indicate the 95% confidence interval.

Figure 6.10 Variations in annual mortality for several regions in southern Quebec



Note: This figure presents expected variations in annual mortality in several of Quebec's administrative regions for scenarios A2 and B2. Variations are expressed as a percentage of historic mortality for the period from 1981 to 1999. Black error bars indicate the 95% confidence interval.



The differences in the projections for cities are not significant, but those for the regions are. Regional projections were obtained using the average of monthly forecast temperature anomalies for stations located in or near the region; this crude approximation may explain some of the differences. Also, climatic variability within a single region may have some effect on the statistically established relationship between mortality and temperature. Nevertheless, projections for the Estrie, Outaouais and Saguenay-Lac-St-Jean regions are similar to those of a major city located within each region (Sherbrooke, Gatineau and Saguenay, respectively).

6.4.3.3 Models and projections by age group

For Montreal and Quebec, models were created by age group. Only two groups were considered: 15 to 64 years of age, and 65 years and over.[5] The 15 to 64 age group seems less vulnerable to heat (the slope is less oblique for temperatures greater than 15°C), but seems more vulnerable to cold, especially in Quebec City, where there is a negative slope for temperatures below 10°C. For the summer period, variations in mortality are approximately two to three times more significant for the 65 and over group than for the 15 to 64 age group.

The main results for the simulations are as follows:

- For the A2 scenario, there was an increase in *summer* mortality of approximately 2% for 2020, 6% for 2050 and 10% for 2080, as well as an increase in *annual* mortality of approximately 0.5% for 2020, 1.5% for 2050 and 3% for 2080. In terms of the absolute number of deaths per year[6] for southern Quebec, this would be an increase on the order of 150 deaths annually in 2020, 550 annual deaths in 2050 and 1,400 in 2080. However, the 95% confidence interval for these figures demonstrates a wide range of possible values that also vary with the climatic scenarios used. On the other hand, these data do not reflect the predictable aging of the population, which will likely tend to increase the number of deaths related to warming.
- This increase affects most regions in Quebec (with the exception of Côte-Nord and Gaspésie) and increases in intensity from east to west.
- There does not seem to be any significant difference among the major cities in Quebec with respect to the vulnerability of their populations to climate change.
- Increase in mortality for the population aged 65 and over is approximately two to three times more significant than that for the group between 15 and 64 years of age.
- The effect of temperature on the 15 to 64 age group seems to change over time. This age group is more vulnerable to temperature increases during the 1991 to 1999 period than during the 1981 to 1989 period.[7]

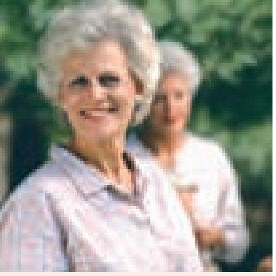
6.4.4 Discussion

Statistical models were developed to establish the relationship between mortality and climate and then predict effects for two scenarios of future climates for Quebec. Projections of mortality were presented for several cities and administrative regions. Projections for the administrative regions had several weaknesses. The development of models required that average temperatures be established for relatively large geographical areas which sometimes included microclimates (such as the Laurentian mountains). In addition, for these large administrative regions, projections for future periods were derived using data from relatively distant stations. Such approximations were not used for cities; therefore, the results for cities were not similarly affected.

5 Not presented here. See Figure 17 in Doyon et al. (2006).

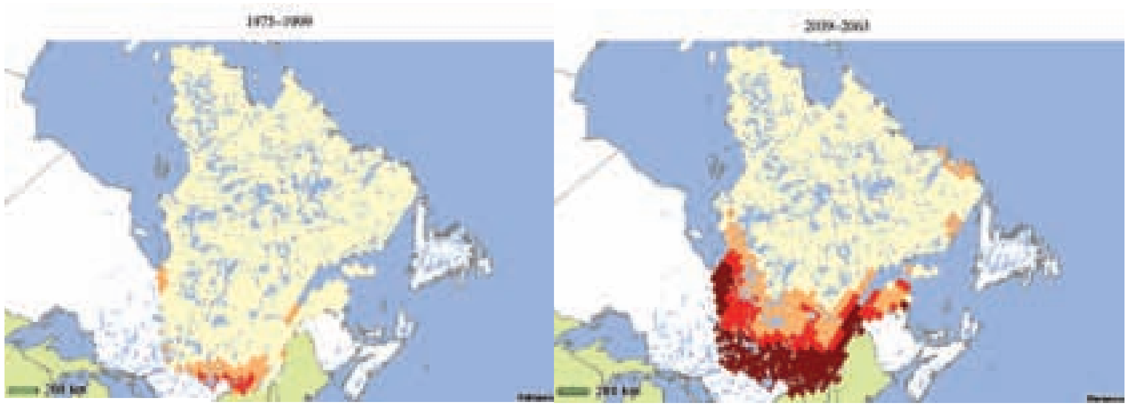
6 See Tables 3, 4, 5 and 6 in Doyon et al. (2006), for a detailed presentation.

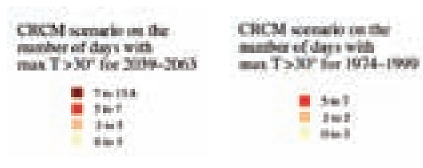
7 Not presented here. See Figure 21 in Doyon et al. (2006).



There is no significant difference among the projections for the various cities. The population density limited the models to regions along the St. Lawrence River, in the Outaouais and in Saguenay-Lac-St-Jean. Projected variations in future climates for this area are very similar and do not show any significant differences in future mortality for the cities considered (Figure 6.11).

Figure 6.11 Current and simulated annual average number of hot days





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

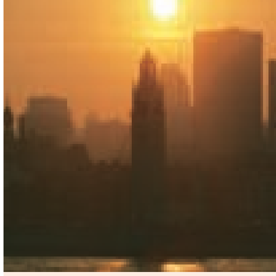
Source: Based on the Canadian Regional Climate Model (CRCM v3.6.1) and the IPCC IS92a emissions scenario and conducted by the Ouranos Consortium in 2005.

In the literature, several publications present projections for variations in mortality for future periods. For example, Donaldson et al. (2001) published projections for the U.K. and several of its large cities predicting annual decreases in mortality. Doyon et al. (2006) obtained the opposite result—an increase in total mortality—for all the cities analyzed. Several factors may explain this difference, such as the ability to adapt to cold and some of the methodology.

As reported by Wilkinson et al. (2001), the excess winter mortality in England between 1986 and 1996 was attributed, among other things, to the absence of central heating and to the high cost of heating. Eventual temperature warming could therefore contribute to decreased winter mortality in this region of Europe. In Quebec, however, the situation is different. In fact, it is unlikely that warming, on average, will affect winter mortality. Over the years, Quebeckers have developed various strategies to adapt to the cold. The *Loi sur l'économie de l'énergie dans le bâtiment* (An act respecting energy efficiency in buildings) (1983), which is intended to ensure minimum performance for heat insulation in walls and ceilings, is an example of an adaptive strategy (*Régie du bâtiment du Québec,* 2006). Furthermore, natural resource endowments in Quebec contribute to the availability of heat at a relatively low cost—one of the lowest of several industrialized countries, including the U.K. (Filion and Lauzier, 2002).

Some methodological differences between the research in this report and that of Donaldson et al. (2001) cannot be ignored. For example, their study did not control for the effect of the seasons. As discussed earlier, controlling for seasons mainly affects the results for the cold portion of the model (Figure 6.6). A model that does not control for this effect will predict fewer winter deaths for future climates. In controlling for the seasonal effect, the increase in summer mortality is not offset by a decrease for the other seasons.[8] The control of seasonal

8 If there is no control for the seasons, the relationship between deaths and cold temperatures seems more significant: the slope of the graph is more significant for cold temperatures when there is no control. If these models are used to predict the variations in winter mortality for future climates (which will be warmer), a significant drop in deaths in the winter is predicted. Inversely, if the seasonal effect is controlled for, the relationship between cold temperatures and mortality decreases, and estimated variations in winter mortality are less significant.



effects is necessary according to Doyon et al. (2006), so that mortality due to climate is not confounded with mortality resulting from seasonal factors (e.g. epidemics). Some other methodological differences also exist in Donaldson et al. (2001). Analyses of Doyon et al. (2006) demonstrate that projections of mortality variations almost double in summer using monthly rather than annual anomalies to derive future temperatures.

A different approach employs air masses in the synoptic scale to establish a relationship between mortality and climate (Kalkstein and Greene, 1997). Using this approach, other researchers have estimated that the number of deaths due to hot days would be approximately three times greater than the decrease in deaths for cold days for several cities in the U.S. This estimate is in line with conclusions by Doyon et al. (2006). It is difficult to compare these results with unpublished work by Kalkstein and Smoyer (1993) cited in Last and Chiotti (2001), who present figures of between 240 to 1,140 additional deaths per year in Montreal; the details of this research (specifically the period for which the projections were made) were not available. Nevertheless, the variations observed for Montreal are within the lower range of those projected for 2050 and in the middle of the range for 2080.[9] More recently, research that was conducted to establish future projections for a few cities in south-central Canada, including climate warming and air pollution levels (Cheng et al., 2005), found the same range of mortality impacts.

With the aging population in Quebec, the percentage of people over 65 will continue to increase. This group grew from 9.7% in 1986 to 12% in 1996 (Pageau et al., 2001) and will reach approximately 28% in 2040 (ISQ, 2000, 2003b). The projections discussed in the preceding text and presented in the related figures were derived for the total population; therefore, these mortality projections can probably be considered as a lower limit that will continue to approach the predictions for a population of 65 years and over, which are two to three times more susceptible to heat-related mortality.

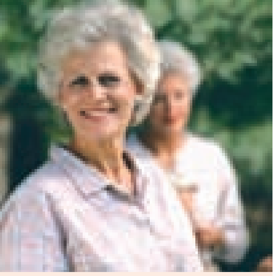
The stability of the model over time is another important methodological issue. It is difficult to anticipate how the population will adapt to climate change. Certain standards may be applied for household air conditioning. Awareness campaigns may have an effect on the vulnerability of individuals most at risk. This issue was addressed briefly, using two models: the first was created with data from the 1981 to 1989 period and the second with data from the 1991 to 1999 period. The idea was to quantify potential changes in the effects of climate on population mortality. For the general population, there were no significant changes in the model and its projections, at least for Montreal and Quebec.[10]

It was noted that the 15 to 64 age group seemed to be more vulnerable to climate change over time. For Montreal, this change was greater for men than for women. An aging population cannot be related to this finding. In the 15 to 64 age group there were more people 50 years and older between 1981 and 1989 than there were between 1991 and 1999. One should therefore expect greater vulnerability to the effects of climate change in this age group in the 1981 to 1989 period than in the 1991 to 1999 period; but the reverse was the case.

This outcome could be attributed to an increase in air pollution that is not taken into account in the models. Because pollution and smog episodes are sometimes correlated with warmer temperatures, the relationship between temperature and mortality obtained by Doyon et al. (2006) could also have been slightly distorted, particularly for the labour force (between 15 and 64 years of age) and more specifically for individuals who work

9 Data not presented here. See Tables 4 and 5 in Doyon et al. (2006).

10 Results not presented here. See Doyon et al. (2006).



outdoors. If air pollution increased significantly between 1981 and 1999, deaths during that period could be statistically attributed to higher temperatures and the conclusion would be that the population is becoming more vulnerable to these temperatures.

It is also possible that this observed difference could be attributed to the small number of deaths, which would modify the stability of the measurement of mortality. On the other hand, average ozone concentrations (ozone being a pollutant associated with an increase in deaths among individuals with chronic pulmonary disease (Lajoie et al., 2003)) in the south of the province continued to increase between 1990 and 2003 (Statistics Canada, 2006). During this period (1990–1999), an increase in deaths from respiratory illnesses, such as obstructive pulmonary disease, specifically among men between 25 and 44 years of age in the Montreal region (Eco-Santé, 2005a), was also noted. Because pollution and smog episodes are sometimes correlated with warmer temperatures, it is possible that certain population groups in the labour force are becoming increasingly vulnerable to higher temperatures (e.g. outdoor workers).

This last hypothesis possibly could be verified by introducing pollution data into the models for Montreal and Quebec. Some authors have already attempted to quantify the significance of temperature effects compared with those for pollution (Kunst et al., 1993; Pattenden et al., 2003; Keatinge and Donaldson, 2006) and agree on the fact that temperature has a much greater effect on mortality than pollution. Recently, other authors have measured this difference for Toronto (Rainham and Smoyer-Tomic, 2003) and reached the same conclusions.[11] Therefore, it is unlikely that the addition of pollution indicators to the models could completely explain the changes in the mortality and temperature relationship for the 15 to 64 age group.

It is important to realize that the models created for this chapter represent the average effect of climate. It is difficult to measure the effect of one heat wave (or other ECE) on death because such events have been historically rare. A binary term has been added to the model to account for heat waves. Between 1981 and 1999, there were heat waves in the province but none were comparable to the one that occurred in France in 2003 (InVS, 2003a).

6.4.5 Next Steps

The increases in mortality simulated by the models created for this report nevertheless remain significant from the point of view of public health. These simulations probably represent the lower limit of the increases in mortality, given the currently aging demographic and the possible increase in global emissions of GHGs and global warming. There are many public health programs addressing risk factors that have much less marked effects on mortality and morbidity. Therefore, this information must be incorporated into planning for the prevention of related risk factors and protection of the health of vulnerable populations.

The most populated areas of the province will be the most affected. Issues of warming and heat waves and their related effects are often perceived in Quebec as affecting only the Montreal area. The data here demonstrate a much larger challenge that affects almost everyone in Quebec.

Finally, it will also be useful to pair these simulations with current demographic models to account for changes in the proportion of seniors and in their residential locations. The simultaneous effect of atmospheric pollution should also be subject to additional analyses.

11 The authors demonstrate that the mortality and temperature relationship for men is the one most influenced by controlling for pollution.

6.5 HEAT WAVES AND COLD SNAPS, AND CURRENT AND FUTURE ADAPTATIONS

6.5.1 Introduction

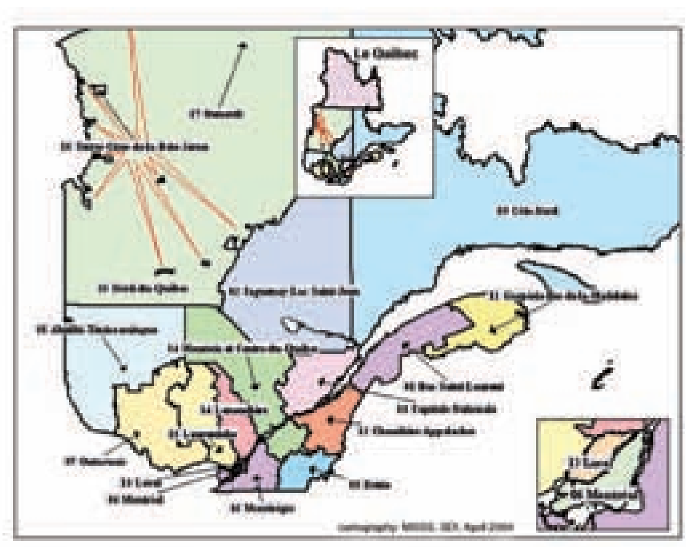
Following on evaluations of the health effects of heat waves and cold snaps, particularly in Europe and North America (Scottish Executive, 2001; Centers for Disease Control and Prevention (CDC), 2004, 2006; WHO, 2005; Centre on Global Change and Health, 2006; InVS, 2006), this section focuses on three studies conducted for this Assessment. These studies examined perceptions and behaviours during heat waves (Bélanger et al., 2006b) and cold snaps (Bélanger et al., 2006c), as well as those concerning the onset of climate change and proposed solutions to alleviate or adapt to it (Bélanger and Gosselin, 2007). Some of the results of a 2005 telephone survey in southern Quebec are summarized and provide an initial response to issues raised by adaptations currently in use for heat waves and cold snaps. Several future adaptation strategies are suggested, a number of which are already the subject of national and international recommendations (e.g. Health Canada, 2001, 2006; Menne and Ebi, 2006). These recommendations include more in-depth research to expand on the investigations that have taken place to date and the implementation of public health measures and public services.

6.5.2 Methodology

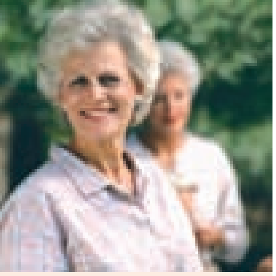
6.5.2.1 Research population

The study population was composed of individuals living in southern Quebec (Figure 6.12) and covering 15 of the 18 socio-health regions (SHR), which include more than 99% of the Quebec population (ISQ, 2006f). The health effects of climate change in the three northern regions (Figure 6.12: regions 10, 17 and 18) are discussed and summarized in Chapter 7, Health Impacts of Climate Change in Canada's North.

Figure 6.12 Socio-health regions in Quebec



Source: MSSS, 2004.



Chapter 6

6.5.2.2 Sample

The sample, stratified according to socio-health region (SHR), residence and post-stratified for gender (Alavi and Beaumont, 2003), was calculated using 2001 Census data (ISQ, 2005b), with a 95% confidence interval and a precision level of 0.35 (Thompson, 1987). The total sample included 5,080 Quebeckers aged 18 years and over; half were contacted during the spring of 2005 and the other half during the fall of 2005.[12] Sampling was conducted by household, based on a random selection of published residential telephone numbers.

Among the respondents,[13] 5.7% lived in eastern Quebec (Figure 6.12: SHR 01, 03, 11); 5.9% in the north of the province (SHR 02, 08); 14.5% in the Quebec City region (SHR 03, 12); 6.5% in central Quebec (SHR 04); 21.0% and 15.7%, respectively, lived south of Montreal (SHR 05, 16) and north of Montreal (SHR 07, 14, 15); 30.6% lived in Montreal (SHR 06) and Laval (SHR 13).[14] A slight majority of respondents were female (51.5%), and the majority was between 35 and 64 years of age (54.7%; 18–34 years: 29.3%; 65 years and over: 16.0%). French was the first language for 81.3% of respondents, English for 5.8%, a language other than French or English for 10.1%, and English or French plus another language for 2.9%.

6.5.2.3 Data collection

A polling company collected the data by telephone (average interview duration: 20 minutes), seven days a week, between 9:30 a.m. and 9:30 p.m., with a computer system that permitted random redistribution of the order of questions. To minimize any bias due to an association with the outdoor temperature on the day of the interview, two rounds of data collection were conducted. The first (from March 16 to April 19, 2005) was to collect information on adaptations to heat waves; the second (September 15 to October 25, 2005) was to collect information on adaptations to cold snaps. Each respondent was interviewed only once.

6.5.2.4 Questionnaire development

Particular attention was paid to the development of the survey questionnaire. It was prepared as follows: (1) a preliminary questionnaire, based on the literature on health and climate change issues, was developed for the interviews (Presser et al., 2004); (2) exploratory interviews (average duration: 2 hours) were conducted with 21 volunteers (≥18 years of age) to check for the comprehension of certain terms (e.g. chronic illness), identify which measurement scales to use and which questions to exclude; (3) a first draft questionnaire was developed; (4) the first draft questionnaire was tested for telephone use (e.g. clarity and accuracy of questions) with 61 volunteers (≥18 years of age) who were recruited by project researchers and public health practitioners working in the 15 socio-health regions under study; (5) the questionnaire content (English and French versions) was validated by five experts working in the field of health and climate change in Canada; and (6) a polling firm pre-tested the French and English versions of the questionnaire (n=50) at the beginning of each round of data collection.

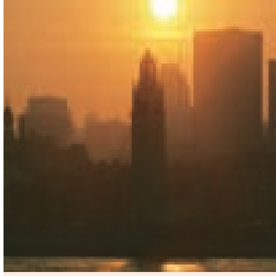
12 For data collected during the spring: 70.2% of those selected (n=3,726) completed the questionnaire; 4.9% were not interviewed because of survey time limits; 6.6% could not be reached; fewer than 1% (n=7) did not complete the interview; 18.2% refused to be interviewed.

For data collected during the fall: 70.0% of those selected (n=3,731) completed the questionnaire, 5.8% were not interviewed because of survey time limits; 7.7% could not be reached; fewer than 1% (n=11) did not complete the interview; and 16,5% refused to be interviewed.

No difference between the percentage of respondents and non-respondents, depending on the SHR of residence, was noted in either data collection ($p \geq 0.4$).

13 With respect to socio-demographic characteristics, no statistical difference was observed between respondents from the first round of data collection (heat waves) and the second (cold snaps).

14 Due to rounding of percentages (to the nearest point), the sum may not total 100%.



6.5.2.5 Information collected

Generally, the information collected from all respondents (first and second rounds of data collection) related to socio-demographic characteristics (e.g. income); health status (e.g. chronic illnesses); housing (e.g. perceived effectiveness of insulation); means of transportation (e.g. use of a car); use of media to obtain weather information (e.g. wind chill index); clothing adaptations as a function of weather; compliance with preventative advisories issued during ECEs; perceptions about the occurrence of climate change (e.g. heat waves); and on current suggested solutions to mitigate or adapt to them.[15] Both the first and second rounds of data collection (heat waves and cold snaps, respectively) addressed ways of cooling (e.g. air conditioning) or heating (e.g. oven) homes, and protection strategies (e.g. toque) for outdoor activities (e.g. running errands) that are used during extreme temperatures.

6.5.2.6 Analysis

The collected data were weighted by calibrating for respondent age and language, on the basis of the 2001 Census data (ISQ, 2005b). The analyses accounted for sampling by socio-health regions. The Rao-Scott likelihood ratio test was used for the bivariate analysis; logistic regression was used for the multivariate analysis (Sautory, 2005).[16] The statistical significance threshold of $\alpha < 0.0001$ was selected because of the high number of respondents.

6.5.3 Heat Waves

6.5.3.1 Current adaptations

Access to and use of air conditioners and fans

Of all respondents, 10.2% had neither a fan nor an air conditioner in their home, 53.9% had only a fan, 26.2% had both a fan and an air conditioner, and 9.6% had only an air conditioner. Almost half of the respondents with an air conditioner (35.8%) had access to a central or wall-based system (a "fixed" versus a "movable" system, such as a window or portable unit).

Seniors (41.3%) more often had an air conditioner at home than younger people (35–64 years, 36.9%; 18–34 years, 31.0%). The same is true for respondents who lived with another person (38.4%) compared with respondents who lived alone (26.1%) and for respondents with higher incomes (≥$60,000 before taxes from all sources within the past 12 months[17], 45.5%) compared with those with lower incomes (<$15,000, 22.1%; intermediary strata between $15,000 and $59,999, 28.5% to 39.4%) (Figure 6.13).

15 Perceptions of climate are discussed in section 6.5.5.

16 The results are not presented here. For more information, see Bélanger et al., 2006b, 2006c.

17 All following income figures are before taxes from all sources within the past 12 months.

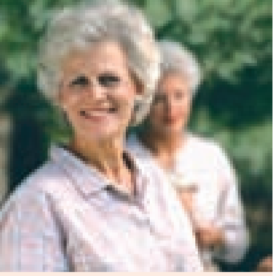
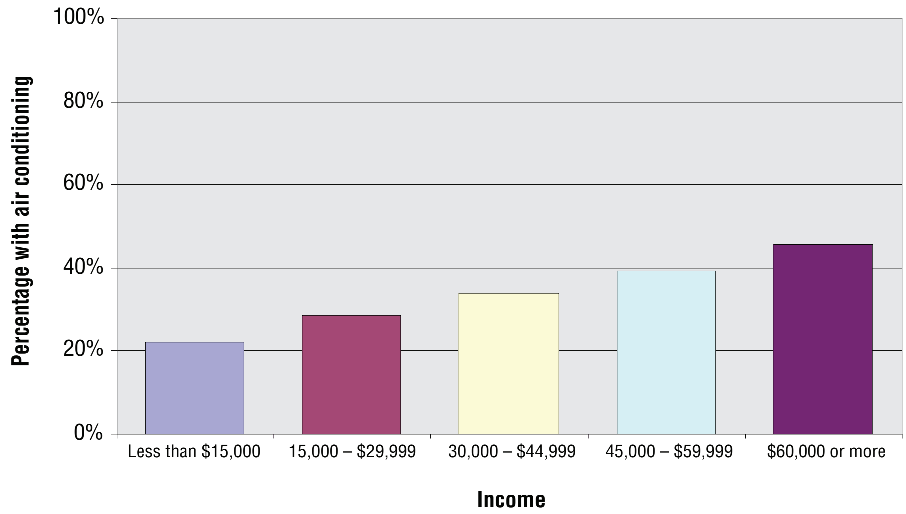
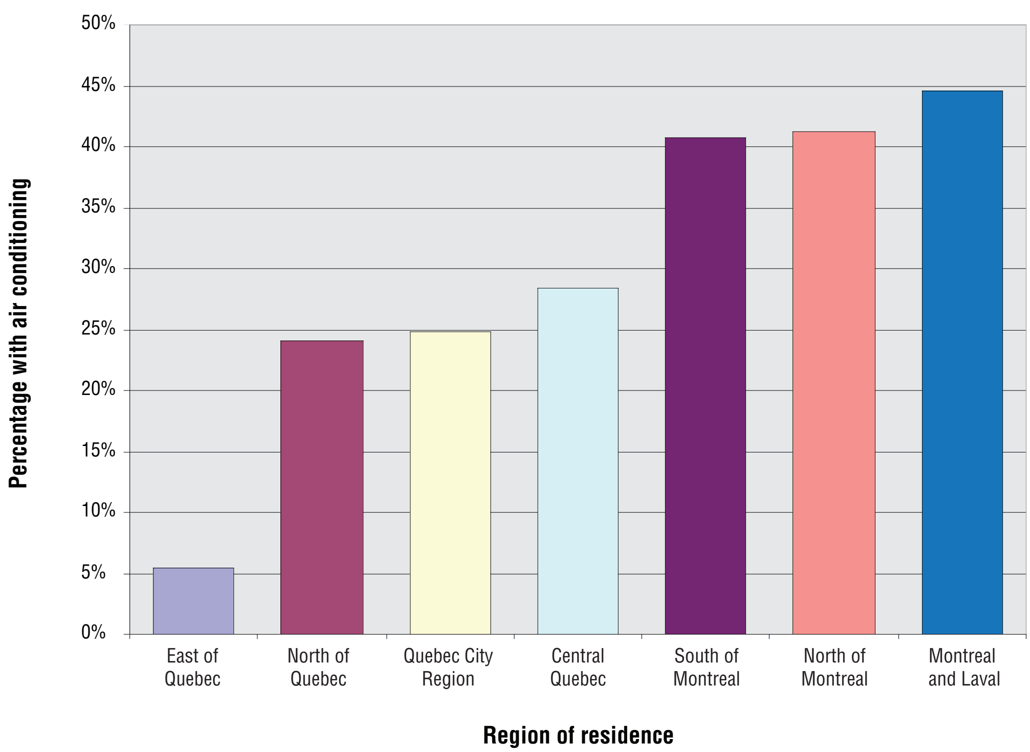


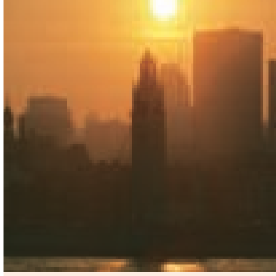
Figure 6.13 Home air conditioning, by income levels



Access to air conditioning also varied by region of residence: 5.4% in eastern Quebec, 24.1% in northern Quebec (south of the 49th parallel), 24.8% in the Quebec region, 28.4% in central Quebec, 40.8% and 41.2% south and north of Montreal, respectively, and 44.6% in Montreal and Laval (Figure 6.14).

Figure 6.14 Home air conditioning, by region of residence





During heat waves, 56.0% of respondents used their air conditioning on a continuous basis (57.6% fixed systems, 42.4% movable systems), 20.1% used it only at night, 21.0% used it only during the day and 1.4% never used it. During heat waves, those who used air conditioning the least during the night were 65 years old and over and had an income of less than $45,000 (58.5%). The second group referred to respondents under 65 years old with approximately the same income (75.5%). Finally, the third and fourth groups included those with better incomes (≥$45,000), first those 65 years and older (79.7%) and then younger (84.8%). Household air conditioning, particularly for fixed systems, was the main reason given by respondents for not opening their windows at night during heat waves.

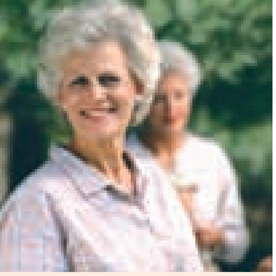
Four out of five respondents owned at least one fan; 42.8% used them during the day and at night during extreme heat, 31.8% used them only at night, 17.3% used them only during the day and 8.1% never used them. Households with air conditioning showed a lower use of fans at night, which was more common among respondents under 65 years (35–64 years, 76.8%; 18–34 years, 79.6%) than among those 65 years and older (55.7%) and among respondents with chronic neurological disease (61.2% day and night, 16.1% night only, 16.5% day only and 6.2% never) than among respondents with other illnesses (43.0% day and night, 24.9% night only, 22.5% and 9.6% day only) or who were not ill (42.2% day and night, 34.7% night only, 15.6% day only and 7.6% never). Respondents who used fans only at night believed their home insulation was less effective, and opened their windows at night more often than other respondents.

Preferred location to cool down during heat waves by housing type

To cool down during heat waves, 62.3% of respondents preferred to remain at home (30.7% in the home and 31.6% on the balcony or in the yard). Approximately half of the respondents had access to an outdoor pool. Others (37.2%) generally went to public locations outdoors; preferred places included beaches or locations beside other bodies of water (15.7%), gardens or parks (9.6%), outdoor pools (7.4%) and places with air conditioning (9.5%).

Compared to apartment dwellers, respondents who lived in houses most often preferred to remain at home to cool down either inside or by their private pools in equal proportions. They were more likely to be between 35 and 64 years of age, have children less than 18 years of age and incomes of $45,000 or more than apartment dwellers. Home dwellers most often lived in a building that that had been upgraded since its construction—either by adding insulation or by replacing doors or windows—and for which insulation was perceived as very effective in controlling humidity. Almost 40% had an air conditioner (fixed, 23.5%; movable, 15.9%).

There were also substantial differences between apartment dwellers living in small versus large buildings, as shown in Table 6.4.



Chapter 6

Table 6.4 Proportions (%) for some characteristics related to residence and behaviour during heat waves

Some characteristics	Home owners	Apartment dwellers (less than 5 floors)	Apartment dwellers (5 floors and more)
Stay home to cool down	69.9	51.2	60.5
Between 35-64 years of age	61.3	44.7	36.8
With children below 18 years of age	36.2	24.3	12.5
No children at all	26.9	49.4	50.7
Incomes over $45,000	50.3	25.4	29.4
Insulation improved since its construction	41.6	26.2	12.1
Doors or windows replaced since construction	65.6	55.7	40.7
Insulation perceived as effective in controlling humidity	40.2	22.4	32.2
Living alone	11.0	35.0	50.4
Access to air conditioning	39.4	28.2	41.5

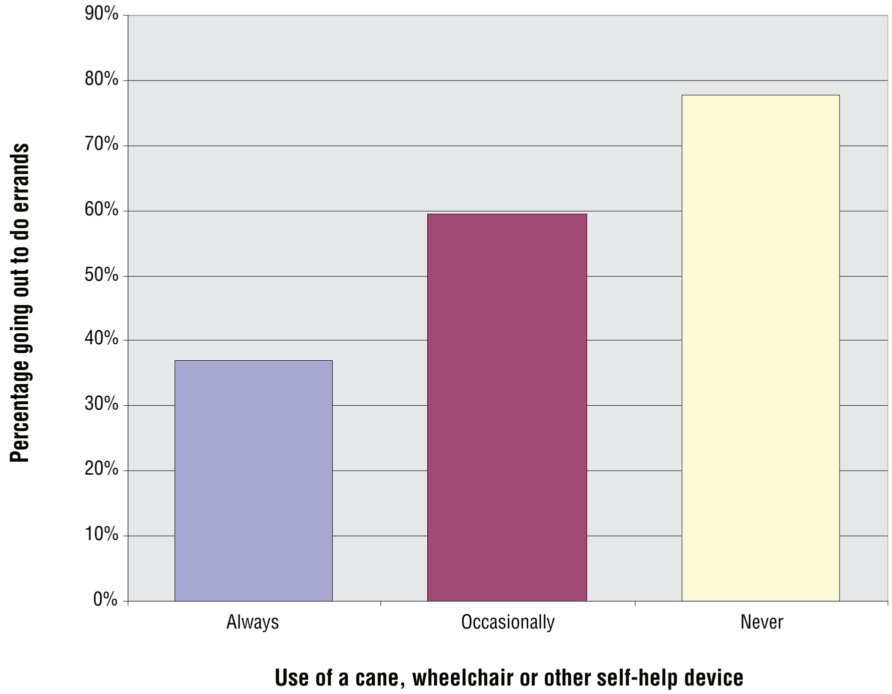
Source: Bélanger et al. (2006b)

Among residents of apartment buildings with five floors and more, 60.5% remained at home during heat waves and more than half of them stayed inside only; 10.2% went out on their balcony; 25.9% had a pool where they lived. These residents were more likely than other respondents to be 65 and older (37.7%) compared to home owners (14.4%) or dwellers in smaller buildings (15.2%). One in two had no children and lived alone. Compared with all other respondents, they were less likely to live in an apartment that had undergone major repairs. With regard to air conditioning, 19.9% had fixed systems and 21.6% had movable systems, for a total of 41.5%.

Residents of buildings with fewer than five floors were the ones who most often left their homes to cool down during a heat wave (48.7%). They were also more often between 18 and 34 years of age (40.1%) than other respondents and had incomes below $45,000. In addition, they were the respondents most likely to consider that the insulation in their homes was not very effective in controlling humidity and were less likely to have air conditioning (4.3% fixed systems, 23.9% movable systems; total 28.2%).

Running errands or participation in physical activity during a heat wave
Heat waves affected respondents differently with respect to their tendency to go out to do errands (e.g. shop for groceries): 28.7% always went out to do errands during heat waves, 20.2% often, 26.9% occasionally, 15.0% rarely and 8.0% never. Respondents who went out at least occasionally were more often employed (80.0%) than unemployed (74.0%), students (74.4%) or retired (68.3%). Respondents who considered themselves in very good (80.1%) or good (77.0%) health were more likely to go out to do errands during a heat wave than those who considered their health to be average (69.3%) or poor (54.3%). Respondents who did not use a cane, wheelchair or other self-help device (77.8%) were also more likely to go out than those who sometimes (59.4%) or always used them (37.0%) (Figure 6.15).

Figure 6.15 Likelihood of going out to do errands (at least occasionally) during a heat wave in relation to the use of a cane, wheelchair or other self-help device

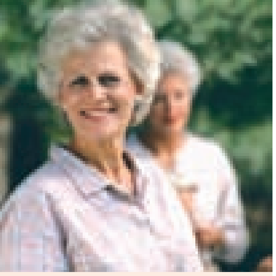


With regard to more intense outdoor activity (e.g. running, mowing the lawn) during extreme heat, the response was: 14.4% always, 16.4% often, 20% sometimes or rarely, 28.5% never. Men (60.2%) were more likely to do so than women (41.5%). Those 18 to 34 years of age (58.6%) were more likely to do so than those 35 to 64 years of age (49.9%) or those 65 years of age and over (37.2%). Students (68.0%) and workers (58.4%) were also more likely to perform manual work and be exposed to the heat than those with less physical demands: professionals (49.3%), unemployed (48.7%) or retired (40.5%). Respondents who believed that ECEs (such as heat waves) had no effect on their own health (56.9%) were more likely to go out than respondents who believed that ECEs had negative effects (44.8% a little, 44.6% moderately, 30.5% a great deal).

Use of sunscreen, sunglasses and hats during heat waves

When it was sunny, 64.7% of respondents often or always used sunglasses (11.8% sometimes, 23.4% rarely or never), 48.3% used sunscreen (16.5% sometimes, 35.2% rarely or never) and 43.4% used a hat (14.3% sometimes, 42.3% rarely or never). When there was cloud cover, 48.1% used sunglasses (15.0% sometimes, 36.9% rarely or never), 34.2% used sunscreen (15.5% sometimes, 50.3% rarely or never) and 31.0% used a hat (14.7% sometimes, 54.3% rarely or never).

When it was sunny, women (76.1%) used sunscreen more often than men (52.8%). Parents of children <18 years old (74.3%) used it more often than parents of children ≥18 years old (60.6%) or respondents without children (59.9%). Respondents with higher incomes used sunscreen more often than those with lower incomes (72.8% with incomes ≥$60,000, 52.7% with incomes <$15,000, 61.2% to 67.7% intermediary strata). Respondents who often or always followed preventative advice issued during ECEs (such as heat waves) (70.3%) also used sunscreen more often than those who followed preventative advice sometimes (63.9%) or rarely or never (49.4%). Gender (80.7% women, 72.1% men) and compliance with preventative advice (81.0% often or always, 73.7% sometimes, 67.2% rarely or never) were also associated with wearing sunglasses, as with the use of a car (80.8% air conditioned, 75.9% no air conditioning, 64.3% no car).



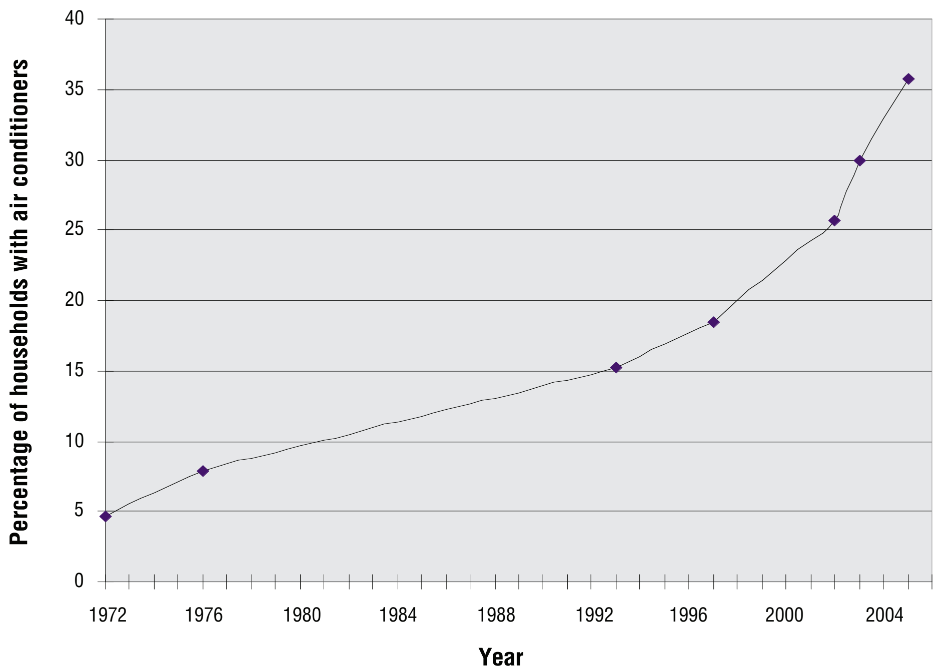
Hats seemed to be worn more by men (66.7%) than women (49.0%) and those over 65 years of age (61.1%) than those 35 to 64 years of age (57.6%) and 18 to 34 years of age (55.7%). It should be noted that some behaviours had become ongoing practices among some respondents; they used sunscreen, sunglasses or a hat even when it was cloudy. There also seems to be a high correlation among these three preventative behaviours relative to their adoption (or not).

6.5.3.2 Suggestions for future adaptations

Air conditioning

The use of air conditioning has been increasing in Quebec for several decades. It has grown from 4.7% of households in 1972 to 15.2% in 1993 to 30% in 2003 (ISQ, 2006c) to 35.8% in 2004 (Figure 6.16).

Figure 6.16 Percent of households with air conditioning in Quebec, 1972 to 2005

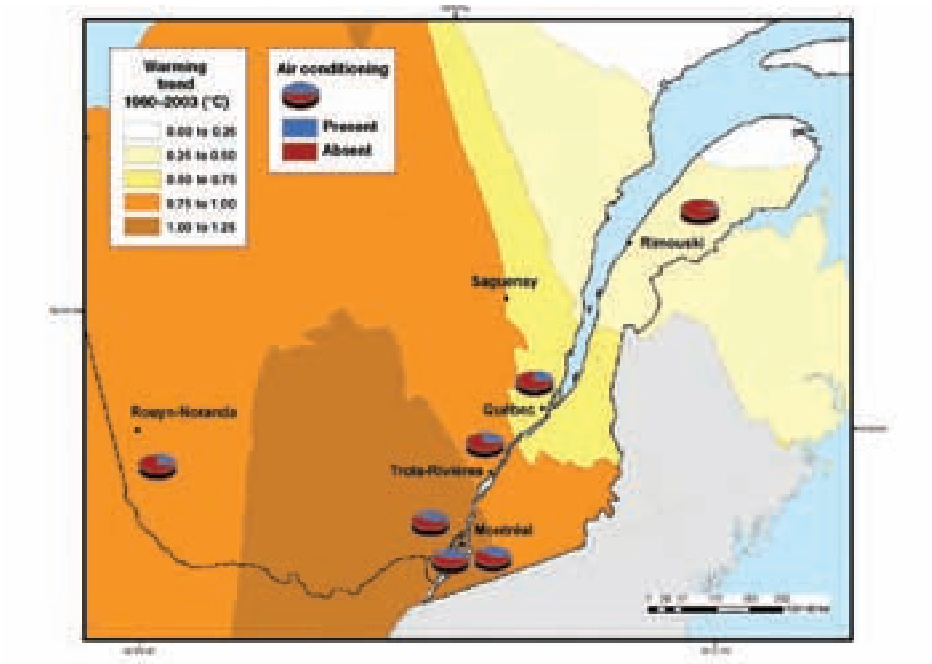


Source: Based on ISQ, 2006c and Bélanger et al., 2006b.

The increase, which appears to have moved from east to west geographically, seems to have started with the temperature warming observed between 1960 and 2003 in southern Quebec (Yagouti et al., 2006) (Figure 6.17). Projected demographic trends for 2026 based on the 2001 census suggest that warming will be more intense in regions where population will grow (ISQ, 2003b). Population increase will inevitably augment the need for air conditioning, particularly because of the increase in urban heat islands associated with greater population densities in southwestern Quebec (Giguère et al., 2006d). As a result, suggestions have been made (Bélanger et al., 2006b) to monitor trends in population growth, heat islands and percent of households with air conditioning to:

- clarify statistics collected on air conditioning (e.g. type of equipment);
- conduct periodic research on temperature changes in correlation with demographic trends; and
- add previous data to an interactive atlas that presents information on maps and graphs, and that is accessible via the Internet to climate change managers and the general public.

Figure 6.17 Percent of household air conditioning in 2005 and increases in average temperatures (1960–2003), southern Quebec



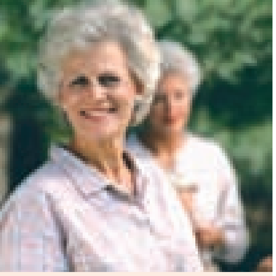
Source: Based on Bélanger et al., 2006b and Yagouti et al., 2006.

Those who are economically disadvantaged were less likely to have air conditioning in their homes. In 2003, 15.8% of households in Quebec with incomes below $20,000 had an air conditioning unit compared with 44.3% of households with incomes of $80,000 and more (ISQ, 2006d). Because those who are economically disadvantaged may be in poorer health (Phipps, 2003), a subsidy program for air conditioning could be considered for homes of the most disadvantaged (including assessment of the space to be air conditioned, purchase, installation and maintenance), especially if health of one of the family members is seriously affected by heat waves according to Bélanger et al. (2006a).

During extreme heat, those 65 years of age and over are one of the most vulnerable groups (InVS, 2004a, 2006). However, although they have air conditioning in the home more often than those who are younger, they use it less frequently at night during heat waves. Identifying the reasons for this would help in the development and assessment of appropriate public health messages and interventions directed at this group.

Respondents who lived in apartments more often had movable air conditioning systems than fixed units; fixed systems are associated with decreases in mortality due to heat (Dixsaut, 2005; Jacques and Kosatsky, 2005) and provide greater comfort than movable units (Vadnais, 2005). An estimate of the number of hours required for movable systems to reach a comfort zone equivalent to that of fixed systems would make an appreciable contribution to public health.

The use of air conditioning in Quebec contributes little to GHGs and air pollution because the power source in Quebec is hydro-electrical. In addition, the power demand for air conditioning occurs during a low energy usage period; peak demand in Quebec is during the winter for residential heating (Hydro-Québec, 2006a). The only other similar situation in North America is in Manitoba; everywhere else, the use of air conditioning generates additional GHGs and air pollutants.



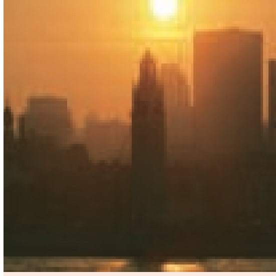
Housing insulation
Several respondents who perceived the insulation in their homes as ineffective in controlling humidity lived in housing built before 1983 and before the adoption of the *Loi sur l'économie de l'énergie dans le bâtiment* (An act respecting the conservation of energy in buildings); this legislation ensures minimum performance for thermal insulation in walls and ceilings (*Régie du Bâtiment,* 2006). More funding for an energy efficiency program—such as that announced in the recent government action plan on climate change (Government of Quebec, 2006e)—should make it possible to improve housing insulation. First priority should be given to economically disadvantaged people, whether they are home owners or tenants, who live in buildings that require major repairs (Bélanger et al., 2006b).

Perceived effectiveness of insulation in controlling humidity was associated with various housing characteristics (e.g. not air conditioned, built before 1983) that may be related in some way to mortality during heat waves (Last and Chiotti, 2001; Auger and Kosatsky, 2002; InVS, 2004a). This perception could be a useful indicator in the area of public health and climate change.

Solutions for cooling homes other than air conditioning and insulation
Respondents who had movable air conditioner systems or who did not have air conditioning at all opened their windows at night during heat waves more often than those who had fixed systems. In certain cases, opening windows may be sufficient to cool the home (Dixsaut, 2005) as could other solutions not documented in this research, such as neighbourhood revegetation (Giguère and Gosselin, 2006d) or the use of basements. In the context of sustainable development, the efficiency and effectiveness of these types of solutions should be explored so more diverse options for heat adaptation (versus only air conditioning) could be assessed.

Neurological illnesses
Individuals with chronic neurological disease used fans at night more often during heat waves than other respondents. This result is not surprising because their health may deteriorate irremediably during extreme heat (Semenza et al., 1999; Green et al., 2001; McGeehin and Mirabelli, 2001). Of particular note was the number of respondents in this group who did not have air conditioning at home. The results of this study indicate that socio-economic factors may contribute to this situation. On the other hand, fans may be preferred over air conditioners for health-related reasons. More information on this issue is extremely important, such as identifying the determinants for the use of fans and air conditioners among this group. However, first priority should be given to understanding what makes those with neurological disease so vulnerable to heat. Such research would support the development of better adapted health care and services, guide public health initiatives implemented during episodes of extreme heat, and likely encourage the expansion of medical criteria and increase the lump sum allocated for the purchase and installation of an air conditioner (maximum of $400) under government programs for assistance with the activities of daily living (MSSS, 2003a).

People living alone
Individuals who lived alone and who were 65 years of age and over, economically disadvantaged and/or had a chronic health problem, lived in housing without air conditioning more often than other respondents. Each of these characteristics (including the absence of an air conditioner) has been considered a "risk factor" during heat waves (InVS, 2003b). "Living alone" could be a useful synthetic indicator for population studies on health and climate change; this characteristic may also be available through census data (Pageau et al., 2001).



It would be desirable to examine, in more detail than in this research, the subgroups of individuals who live alone and who are most at risk during extreme heat (Klinenberg, 2002), in addition to identifying the services these subgroups would need to ensure their safety during ECEs. This information could support front-line workers associated with emergency measures, and the implementation and assessment of such measures. In addition, research to understand why "reclusive" people or those who "feel alone" are difficult to reach would be a major asset in identifying appropriate and timely actions to take during ECEs for individuals in this group, whether they live alone or not. It would be important to distinguish between social factors (e.g. support, socialization) and housing factors (e.g. location in the building, such as on the top floor, or in a building with several floors) in relation to their effects on health during extreme heat (Auger and Kosatsky, 2002; InVS, 2004b). The examination of various cultural communities (Klinenberg, 2002) that are often grouped together in certain neighbourhoods (Laverdière, 2001) would also add important information.

Running errands during heat waves

Respondents who usually use canes, wheelchairs or other self-help devices when going out of the home rarely if ever went out to do errands (e.g. groceries) during heat waves, particularly if they were seniors. The reasons they stayed at home were not collected during this research, but it is likely that those in the *Enquête québécoise sur les limitations d'activités* (Quebec survey of activity limitation) (ISQ, 2001) may be applicable—in particular, feeling insecure outside the home, aggravation of health problems, the need for help upon arrival at the destination, the use of non-portable self-help aids, unavailability of an attendant and the lack of adapted public transportation. Such findings are of concern (Bélanger et al., 2006b) because they relate to the additional stresses that may be faced by individuals in this group during heat waves, as well as to the range of services that can be provided for their assistance in the absence of adequate social support. From the point of view of assistance and public health, it would be crucial to collect information on the needs of this group and propose a range of services that respects their physical limitations and attendant fears (e.g. fear of opening the door to a delivery person).

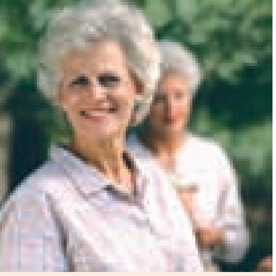
Public places used during heat waves

To cool down during heat waves, people who live in apartments are much more likely to go to public areas than those who live in houses. For this group, the most effective collective actions to address the health effects of extreme heat would be financial support to municipalities and neighbourhood organizations to (1) improve and conserve "free," cool, public areas located in urban environments (e.g. parks and gardens) and (2) implement a support program for municipalities and neighbourhood organizations (Government of Quebec, 2002) to develop the public access network to bodies of water. Over one million Quebeckers participate in swimming and beach-related activities annually (Government of Quebec, 2002). Temperature warming will increase participation in these activities as well as the size of beaches because of drops in water levels (NRCan, 2002). Consequently, better surveillance and vigilance will be needed to protect both the environment (e.g. erosion, pollution) and the population (injuries and drownings.)[18]

Private pools

The number of private pools throughout the province is impressive: 31% of respondents had pools at home compared with 24% in 1997 (NRCan, 1997). An assessment of their effectiveness would be useful; however, filling pools will inevitably become a source of conflict during times of water use restrictions. Regulating the use of water to fill private pools and implementing mechanisms to ensure enforcement would also be potential adaptation strategies (Giguère and Gosselin, 2006d).

18 Drowning was the main cause of death during recreational and sport activities in Canada between 1991 and 2000 (Canadian Red Cross, 2003).



Chapter 6

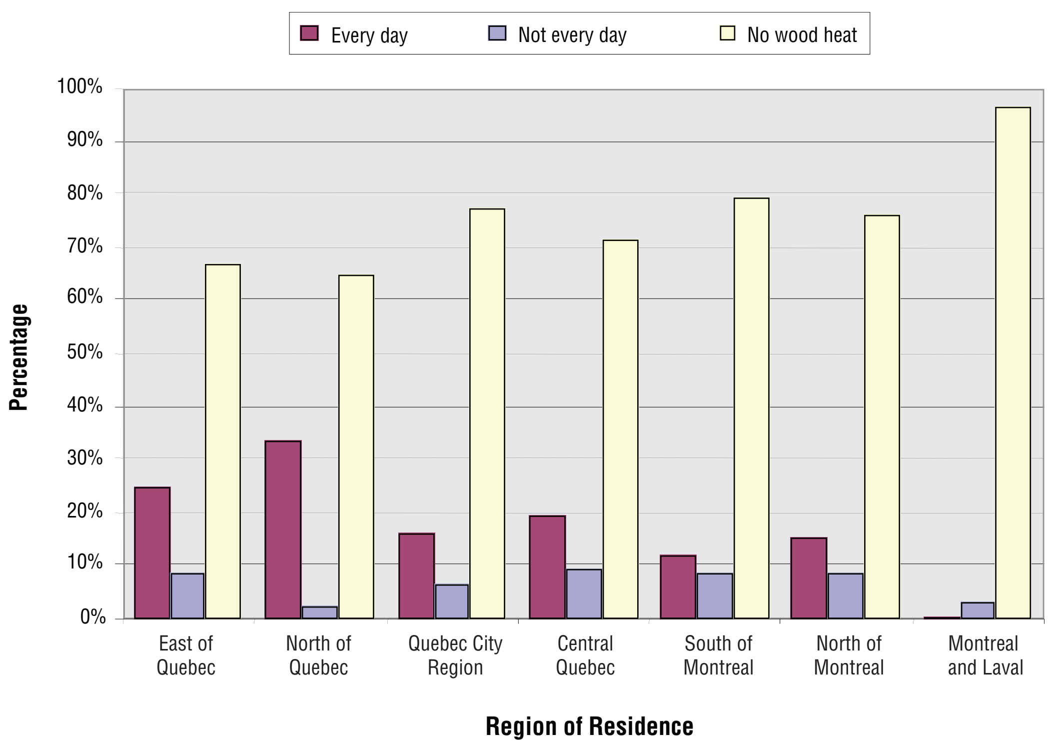
Safety practices for sun exposure during heat waves
The adoption of preventative behaviour to protect against sun exposure (whether or not there is sun) and the close correlation of the use of sunscreen, sunglasses and a hat (Bélanger et al., 2006b) demonstrate the importance of habit in maintaining behaviours (Triandis, 1979; Van der Pols et al., 2005). It also suggests that certain common factors, such as habits, will facilitate the design, short-term adoption and long-term integration of a behaviour into daily life (Ory et al., 2002; Solomon and Kington, 2002; Strecher et al., 2002). Currently, very little is known in the area of the complex interactions among the factors that contribute to certain preventative behaviours (e.g. sequentially, concomitantly). Information on the various factors that contribute to the observance and reinforcement of safe behaviours related to sun exposure could complement public health interventions. Improving knowledge in this little-known area could also significantly improve the understanding of other environment-related behaviours (e.g. recycling, composting, reclamation).

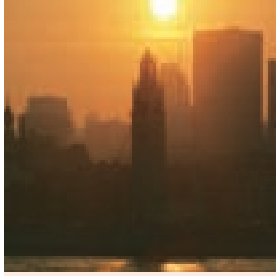
6.5.4 Cold Snaps

6.5.4.1 Current adaptations

Type of heating used in the winter
More than three quarters of respondents had access to only one source of energy for heating their homes in the winter, primarily electricity (60.8%), while 22.2% combined more than one source, particularly electricity and wood. The prevalence of wood heat (18.5%) was higher among those who lived in houses (28.1%) than apartments (3%) and among those (23.6%) with the highest incomes (≥$45,000) than among those (16.8%) with lower incomes (<$45,000). The use of wood for heat is more frequent outside of Montreal and Laval (Figure 6.18). The use of wood for heat is not affected by smog warnings or by the perception of living in a region subject to winter smog.

Figure 6.18 Percentage and frequency of residences using wood heat, by region of residence





Caulking of openings
In the winter, 12.4% of respondents caulked all windows and doors in their homes and 19.3% caulked some. This strategy was used more often by respondents living in buildings built before 1983 (35.9%) than in or after 1983 (21.8%) (Figure 6.19) as well as by respondents who perceived their home insulation to be ineffective against the cold (55.9% compared to 24.1% when very effective), and ineffective in controlling humidity (49.6% compared to 27.1% when very effective).

Figure 6.19 Prevalence of caulking of openings in houses, by year of construction

Adaptation strategies for heating homes during cold snaps
During cold snaps, 27.7% of respondents at least occasionally added weather stripping to their windows (e.g. rags) and doors (e.g. carpeting) in their homes. Inefficient home insulation against cold or for controlling humidity seemed to encourage such solutions, particularly among respondents who had never caulked openings in their home.

During periods of intense cold, 23.3% of respondents increased heat during the day, if at home (34.2% sometimes, 42.5% never); 33.8% of respondents at least occasionally increased it at night compared with 67.1% who never did. The tendency to increase heat during the day was greater among men aged 18 to 34 years and women of any age, but particularly among young women (Figure 6.20). At night, it was more common among those aged 18 to 34, allophones and those who had increased it during the day.

More than 10% of respondents used a portable heater during cold snaps: 3% often or always, 8.7% occasionally, 88.6% never. Respondents who used portable heaters most often considered the insulation of their homes to be only somewhat effective, or even ineffective, in fighting the cold. They also most often lived in a home built before 1983.

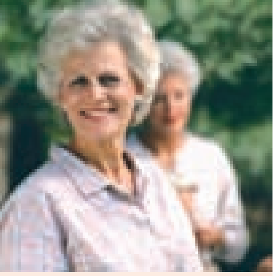
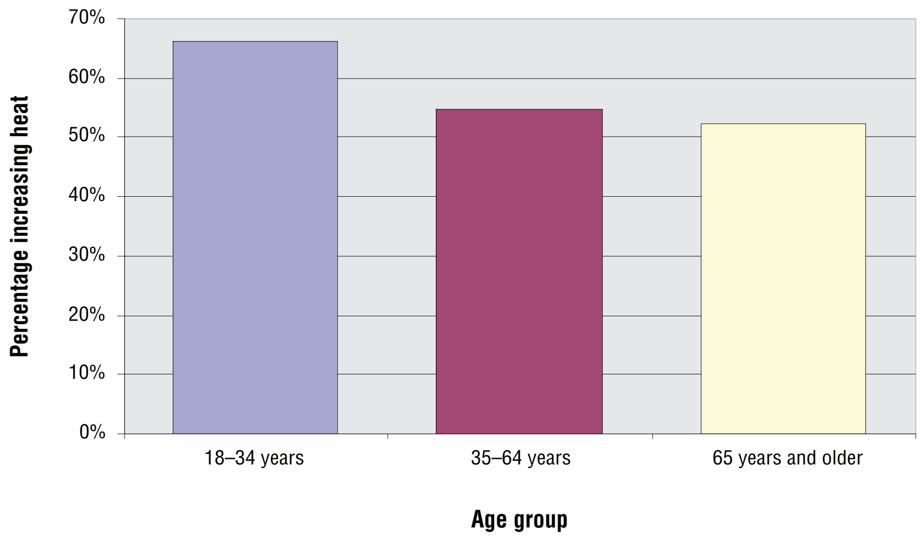


Figure 6.20 Tendency to increase heat during the day during cold snaps, by age



Twelve percent of respondents used their oven to heat their home during cold snaps: 3.7% often or always, 8.2% occasionally and 88.0% never. These respondents also used various other strategies to adapt, particularly portable heaters.

Most respondents (85.9%) opened the draperies or blinds on sunny days during periods of intense cold (6.5% sometimes, 7.6% never), while one-third at least occasionally closed them when it was windy (17.8% often or always, 17.1% sometimes, 65.1% never). Most allophones closed their curtains.

When temperatures dipped below normal, respondents—particularly men aged 18 to 34 and women of all ages, but particularly younger women—used other ways to keep warm at home, including wearing warmer clothes than usual (47.7% often or always, 29.2% sometimes, 20.3% never), using a blanket (e.g. to read or watch television) (39.4% often or always, 30.5% sometimes, 30.0% never), or taking hot showers or baths (10.9% often or always, 28.3% sometimes, 60.7% never).

Finally, 52.7% of respondents reported using at least six coping strategies for keeping warm at home (e.g. using a blanket) or heating their home (e.g. using the oven) during cold snaps, while 37.8% mentioned three to five and 8.7% mentioned one or two (0.8% mentioned none). Five groups of respondents used a higher number of solutions (i.e. women aged 18 to 34, respondents who considered their home insulation to be ineffective in controlling humidity, respondents who did not caulk the windows or doors of their homes, and respondents residing in the socio-health regions covering Montreal, Laval, the Montérégie and the Outaouais).

Outings for shopping or intense physical activity during cold snaps

Approximately 50% of respondents often or always ran errands (e.g. groceries) during abnormally cold temperatures, whereas 28.6% did so occasionally and 19.9% rarely or never did so. Similarly, one third of respondents, or 33%, often or always engaged in intense, physical outdoor activities (e.g. shovelling snow, sports), whereas 26.1% did so sometimes, 18.1% rarely and 21.8% never. Respondents who ran errands or engaged in intense, physical outdoor activities were more often men than women, as well as those who saw themselves as being in good or very good health. In addition, workers and students went shopping more often than people who were unemployed or retired. Those living in houses engaged in intense outdoor physical activities more often than respondents living in apartments.

During such outings, some 75% of respondents always wore warmer clothing than usual. Only 44.4% of respondents always wore warmer footwear than usual. The most popular accessory was gloves (74.3%, always), followed by neck warmers and head coverings (63.5%, always). Face coverings were the least used (25.2%). Generally, those aged 18 to 34 and 35 to 64 (to a lesser degree) used these adaptation strategies more often than older respondents. Use of an automobile also seems to be associated with the greater use of gloves and warmer clothing. No difference was noted in behaviour according to knowledge of the wind chill factor for any type of outing during a cold snap.

Use of a remote car starter in the winter

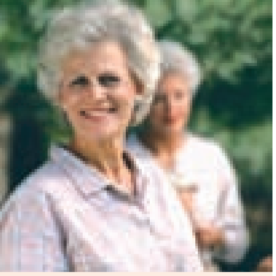
More than one half of respondents (56.8%) used a car every day, while 27.0% used a car less than once per day and 16.2% never did. The use of a remote starter in the winter was 32.9% among respondents using their car on a daily basis and 27.4% among those using it less frequently. More women (35.3%) than men (27.1%) used a starter. Use of a starter was also more common in the colder regions of southern Quebec. Bélanger et al. (2006c) reported that neither smog warnings nor the perception of living in a region subject to winter smog influenced the use of a remote starter in the winter.

6.5.4.2 Suggestions for future adaptations

Wood heating

In Quebec, residential wood heating increased by approximately 60% from 1987 to 2000 (MDDEP, 2006b), particularly following the 1998 Ice Storm (Télasco, 2004). This trend is worrisome because this type of heat is responsible for half of human-made fine particulates released in Quebec. These particulates, like some gases generated by wood combustion, can affect human health. Two factors should not be underestimated: the increased frequency and intensity of ECEs (NRCan, 2002), which could encourage Quebeckers to burn more wood, and the recent and future increase of the Quebec population in the regions surrounding Montreal (ISQ, 2006f) where the prevalence of wood heating is already relatively high.

With a view to protecting public health, the trend toward heating with wood should be monitored (Bélanger et al., 2006c). Additional information to characterize the exposure and potential risk (e.g. type of equipment, year acquired) would be an asset. At the same time, as suggested in a Canadian Council of Ministers of the Environment feasibility study for a program to raise awareness and replace conventional residential wood heating equipment (Del Matto et al., 2004), it seems important to implement a strategy in stages, with various actions to be taken jointly. These include (1) the adoption of national legislation prohibiting the sale of wood heating equipment not certified by the U.S. Environmental Protection Agency (USEPA, 1988), along with the application of enforcement measures; (2) the implementation of an awareness campaign regarding certified equipment; and (3) the implementation of a long-term national program for replacing conventional equipment, including recycling and promoting various solutions to address the obstacles to using the new wood heating equipment, such as the cost of purchasing and installation. Incentives to replace uncertified wood stoves (set at $320 per stove) seem to be insufficient in some cases (Del Matto et al., 2004). More generous support of low-income households so they can access new, less polluting technology is also suggested (Bélanger et al., 2006c).



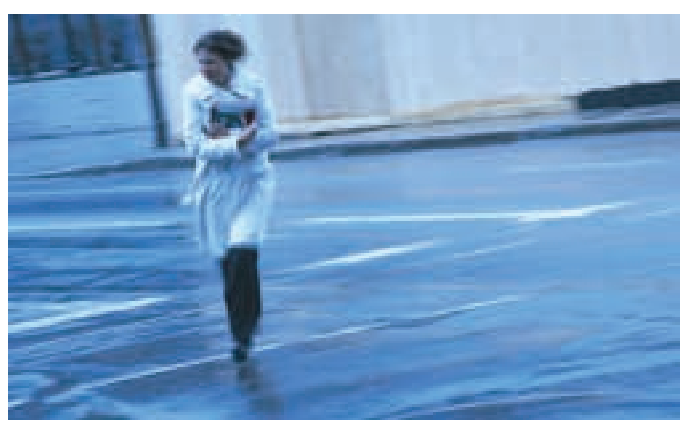
Winter adaptation strategies used at home during cold snaps
The combination of certain characteristics of housing and occupant income provides a reasonable basis for identifying certain subgroups of people at high risk during periods of intense cold (Wilkinson et al., 2001). With a view to public health and energy savings, however, it would be best to develop assistance programs for improving home insulation, more suited to the economic reality of less well-off Quebeckers (Hydro-Québec, 2006c), whether owners or tenants (Bélanger et al., 2006c), and to implement attractive incentive programs for energy efficiency.

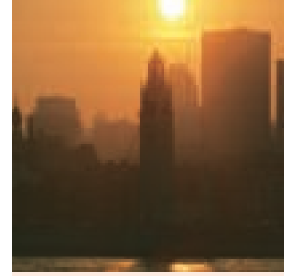
The preventative caulking of doors and windows in the winter—a concrete, cost-effective measure for conserving energy at home (NRCan, 2006c)—could be used more. A study identifying the reasons for the use of caulking would help further messages about conserving energy (Bélanger et al., 2006c).

The parameters of this study did not include identifying physiological and psycho-social factors that affect strategies for keeping warm at home during periods of intense cold (e.g. wearing warmer clothes than usual). From a sustainable development perspective, further examination might be warranted because, although a major decrease in the number of heating degree-days is likely in the future (compared with the period from 1961 to 1990) (Chaumont, 2005), it is also possible that the physiological ability of young people to adapt to the cold could be reduced and in turn this could reduce possible energy savings.

Immigrants, particularly those from tropical regions, must make greater adjustments to extremely low temperatures compared with the residents of colder regions, who are much better adapted to the cold physiologically, socially and culturally (Beaudreau et al., 2004). These immigrants are among the most vulnerable in winter, particularly those of the first generation. Included among their difficulties are language and lack of resources, often including lack of family support; during emergencies, such as a widespread power outage, their abilities to cope are further compromised by these difficulties (Bélanger et al., 2006a). If they have not already done so, emergency measures officials should collaborate with Hydro-Québec, which has already implemented programs aimed at cultural communities in partnership with welcome and integration organizations. These active outreach programs in several languages are aimed at communities of unilingual allophones (Hydro-Québec, 2006c). This approach may be increasingly important if certain ECEs increase in frequency and intensity.

Simultaneous broadcast of wind chill index and clothing recommendations
The study by Bélanger et al. (2006c) did not measure understanding of the wind chill index but documented the absence of behavioural response to it. It appeared that the wind chill index and accompanying Environment Canada recommendations for clothing during intense cold warnings play little or no part in the choice of clothing for outings. This may be because adaptive behaviour depends on many factors (e.g. attitudes, habits, social and cultural influences) other than knowledge (Fishbein et al., 2001; Core Group, 2003). It may also be because the wind chill index is not clearly understood. This index combines two measurements—temperature and wind speed—in a formula that





attempts to quantify a sensation (Tremblay, 2003), and that can vary by gender, age and the body part exposed (Harju, 2002), as well as other factors, such as the state of health (Beaudreau et al., 2004) and the geographic location of residence (Mäkinen et al., 2004). The validity of the wind chill index among the general population had been questioned (Bélanger et al., 2006c) on the basis of its development; just six men and six women, aged 22 to 42, wearing appropriate cold weather clothing were exposed with only the face showing (Environment Canada, 2001). Assessing the understanding of the wind chill index and its impact on the use of appropriate clothing worn outside in the winter is important. It would also be very useful to verify the influence and validity of this index for the general public, including several age groups, socio-economic conditions (e.g. ability to buy thermal clothing) and health conditions (e.g. heart, respiratory), and to identify indicators of compliance with the clothing recommendations issued by Environment Canada during intense cold warnings.

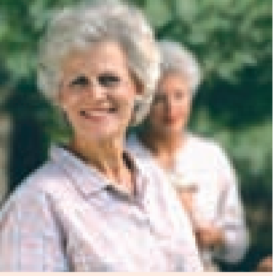
Use of a remote car starter

Four out of five respondents owned a car, and approximately a third used a remote starter in the winter, particularly women (Belanger et al., 2006c). No information helped to identify the reason for this variation by gender, such as a greater perception of cold among the latter (Harju, 2002) or distinct clothing habits (e.g. hats worn by men). There could be other reasons as well (e.g. the habit of idling and the popular belief that "it is good for the engine") (NRCan, 2006b). More specific research into determinants in remote starter use could clarify this matter. The identification of determinants in remote car starter use could be useful in developing initiatives to discourage idling (Bélanger et al., 2006c). Such research is also recommended in terms of public health and environmental protection. Idling contributes to atmospheric pollution which is a major cause of health concerns, given its effects on mortality and morbidity, particularly among children, people with respiratory or cardiovascular illnesses and seniors (Quénel et al., 2003)—all groups deemed to be highly vulnerable during ECEs (MacCracken et al., 2001).

Smog warnings

Info-Smog informs the public of meteorological conditions that are conducive to increased atmospheric pollution. It also gives advice on how to reduce the health effects of smog and sources of pollution, such as automobile combustion and wood heating (Environment Canada, 2006a, 2006b; Health Canada, 2006). This program was created in 1994; a winter component has been included since 2001. The geographic area covered has increased over the years and Info-Smog currently covers almost all of southern Quebec. The new national health risk-based Air Quality Health Index (AQHI) is also planned for demonstration in 2007–2008 (Health Canada, 2006).

Studies indicate that smog warnings do not significantly affect the behaviour of the population where and when they are issued (Bélanger et al., 2006c; Tardif et al., 2006); they have not affected the use of cars, remote car starters or wood heat in winter. A possible explanation is that respondents most frequently using a car or wood heat live in regions where smog warnings have been only recently introduced. However, respondents living in the greater Montreal region act no differently than others and they have had access to the information almost since its inception (in 1994 for summer smog and 2001 for winter smog). Identification of the determinants related to the adoption of advice given in winter smog warnings could improve the Info-Smog program. This being said, it is essential to invest in other concrete measures to reduce atmospheric pollution, such as mass transit infrastructure and the development of cycling paths (Government of Quebec, 2006a). In this regard, the recent announcement in the *Québec and Climate Change, A Challenge for the Future. 2006–2012 Action Plan* is a major signal in this direction (Government of Quebec, 2006e).



6.5.5 Current Perceptions of Climate Change and Future Adaptations

6.5.5.1 Current perceptions

Extreme climate events and smog

The extreme climate events that were perceived as being the most likely to occur in each study region (Bélanger and Gosselin, 2007) were cold waves (35.1% very likely, 45.1% moderately likely, 15.3% somewhat likely, 3.9% not at all likely) and heat waves (27.4% very likely, 47.9% moderately likely, 18.5% somewhat likely, 6.1% not at all). However, respondents residing in the northernmost portion of southern Quebec viewed their region as far more subject to wildfires than to heat waves. As for other extreme weather events, approximately 60% of respondents considered their region to be very or moderately subject to storms; 50% to ice storms; 40% to droughts; 20% to floods or wildfires; and fewer than 10% to tornadoes, landslides or avalanches. Finally, 20% of respondents thought their region of residence was very likely to experience smog in summer (27.5% moderately likely, 27.4% somewhat likely, 25.3% not at all), whereas 7.6% thought their region was very likely to experience smog in winter (20.8% moderately likely, 28.1% somewhat likely, 40.0% not at all); this was particularly true of Montreal and Laval residents.

Strategies to reduce greenhouse gases and adapt to climate change

Most respondents "agreed completely" with many of the 32 strategies (Table 6.5) put forward to reduce GHGs, adapt to climate change and reduce the harmful effects of these changes on population health and well-being (Bélanger and Gosselin, 2007).

Table 6.5 Greenhouse gas and climate change adaptation strategies

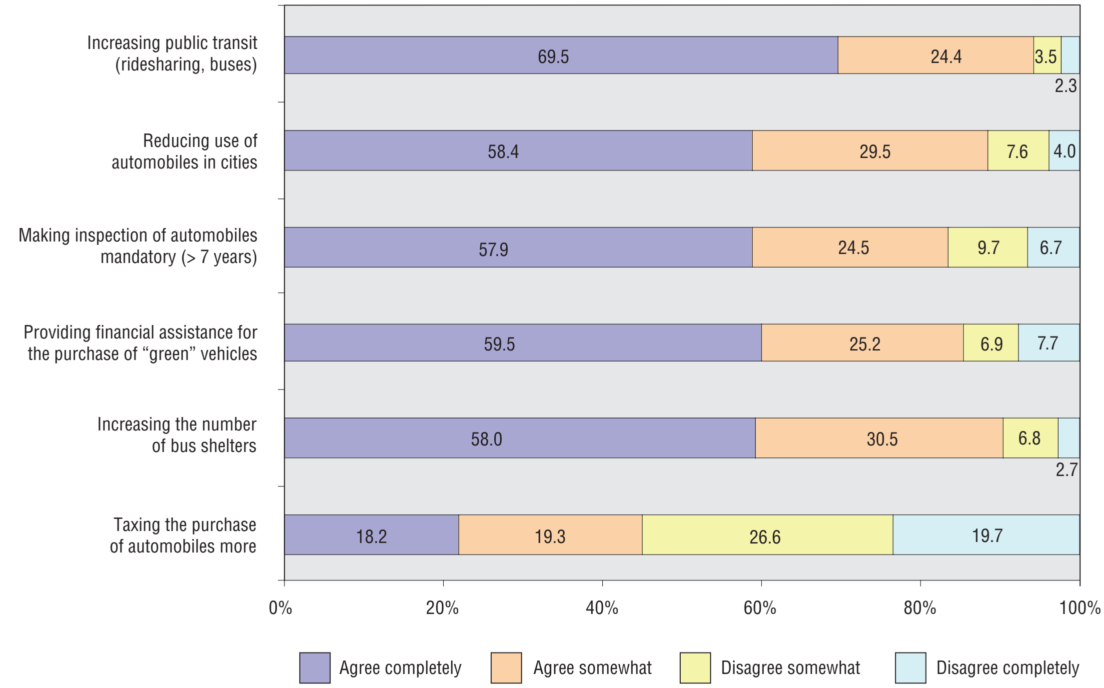
Business and industry
• increase monitoring of commercial and/or industrial pollution • increase monitoring of forestry practices • increase monitoring of agricultural pollution • ban construction of oil- and gas-fired power plants
Land use
• plant trees in recreational areas and schoolyards • plant trees in city centres • turn vacant lots and public lands into parks and gardens • rehabilitate beaches and river banks • prevent construction of houses, cottages and other residences in risk zones (e.g. flood zones) • plant trees in large outdoor parking lots
Infrastructures
• increase recycling in all municipalities • repair and improve water supply systems and aqueducts • rebuild roads to make them more resistant to freeze-thaw cycles and erosion • increase the number of municipal pools and parks with fountains • introduce a consumption tax on drinking water
Buildings
• install air conditioning in homes for sick persons and seniors • install air conditioning in hospitals • improve insulation standards for residences and rental housing • subsidize home air conditioning for seniors and low-income people • subsidize air conditioning for daycare centres • ban wood burning in the winter when smog is severe

Transportation
• increase public transportation (car pooling, buses) • implement financial incentives for the purchase of "green" vehicles • reduce the use of cars in large urban centres • increase the number of transit shelters • make vehicle inspections mandatory (seven years and older) • expand air conditioning on buses • make air conditioning a standard feature in new vehicles • increase the sales tax on new vehicles
Social measures and research
• expand home care services for sick persons and seniors on low incomes • increase the number of homeless shelters • increase funding for health and climate change research

Source: Bélanger and Gosselin, 2007.

On average, respondents agreed with 19 strategies; 4.2% with fewer than five strategies, 7.6% with five to nine strategies, 13.0% with 10 to 14 strategies, 21.4% with 15 to 19 strategies, 29.1% with 20 to 24 strategies, and 24.6% with 25 to 32 strategies. Some results are presented for transportation (Figure 6.21) and housing (Figure 6.22).

Figure 6.21 Transportation: Solutions to reduce the harmful effects of climate change



Source: Bélanger and Gosselin, 2007.

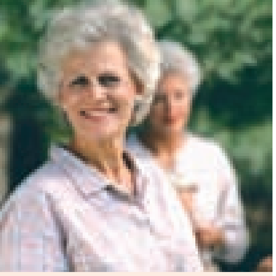
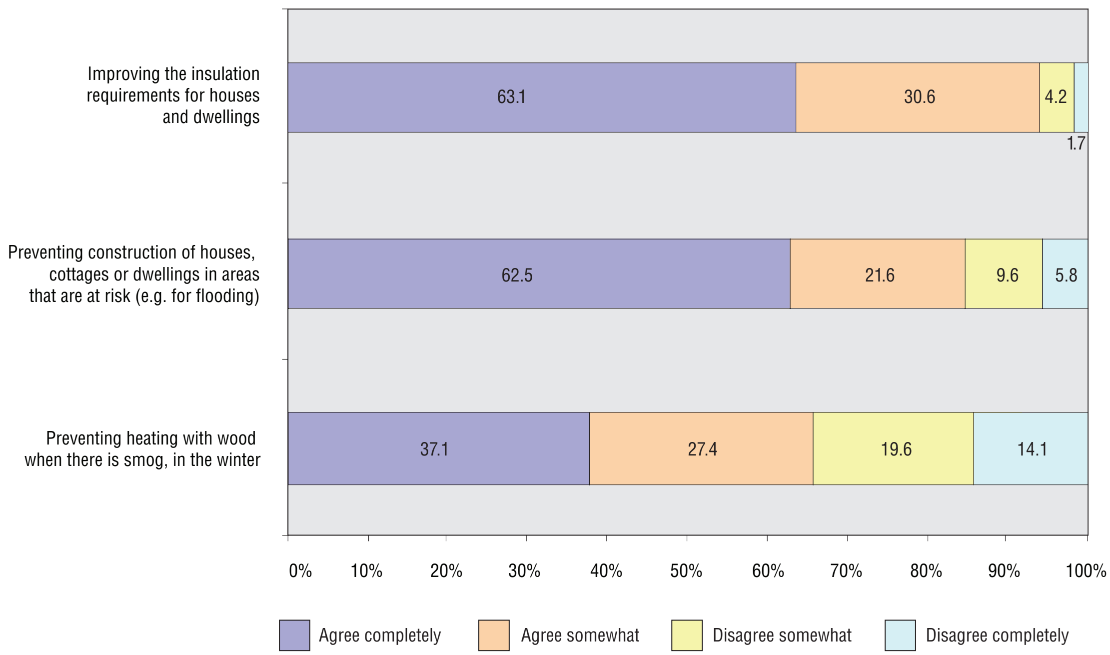


Figure 6.22 Housing: Solutions to reduce the harmful effects of climate change



Source: Bélanger and Gosselin, 2007.

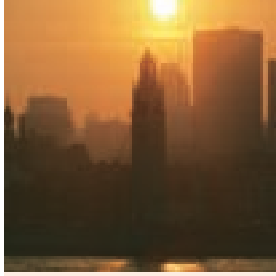
Almost 67% of respondents were in favour of at least three of the four strategies relating to business and industry. Some 82% were in favour of increased monitoring of commercial and industrial pollution, 78% were in favour of stricter controls over forestry practices, 67% were in favour of increased monitoring of agricultural pollution and 53% were in favour of banning the construction of oil- and gas-fired power plants.

Some 66.9% were in favour of at least four of the six land use strategies. Approximately 75% of respondents wanted trees planted in recreational areas, schoolyards and city centres. Some 66% of respondents were in favour of creating beaches (including along rivers) and transforming vacant lots and public lands into parks and gardens. Slightly more than 60% were in favour of planting trees in large outdoor parking lots in cities and also banning residential construction in risk zones.

A little over 70% of respondents were in favour of at least three of the strategies pertaining to infrastructures. Specifically, 83% of respondents wanted more recycling; 76% were in favour of rebuilding roads to make them more resistant to freeze-thaw cycles and erosion, as well as repairing and improving drinking water supply systems; 43% were in favour of increasing the number of municipal pools and the number of parks with fountains; and 32% were in favour of a consumption tax on drinking water.

Half of the respondents were in favour of at least four of the six building-related strategies. Fully 66% approved of air conditioning in hospitals and homes for sick persons and seniors; 63% were in favour of improving residential insulation standards; 52 and 45% were in favour of subsidizing home air conditioning for seniors and low-income people, as well as for daycare centres, respectively; and 37% were in favour of banning wood burning at times when smog is severe.

Close to 60% of respondents agreed with at least four of the eight transportation strategies. Some 70% were in favour of increasing public transportation; 60% approved of financial incentives for the purchase of "green" vehicles; 58% approved of reducing the use of cars in large urban centres, as well as increasing the number of transit shelters and introducing mandatory inspections for vehicles seven years old and older. Finally, 36% favoured air conditioning for buses, 29% wanted air conditioning as a standard feature in new vehicles and 18% favoured higher sales taxes on new vehicles.



6.5.5.2 Suggestions for future adaptations

Extreme climate events and smog

Perceptions of ECEs demonstrate that some events (e.g. such as cold snaps) are of concern to everyone to some degree whereas others (e.g. wildfires) are contingent upon regional geophysical and geomorphological characteristics. Overall, these perceptions also appear to reflect reality (Klaassen et al., 2003; Warren et al., 2004; Yagouti et al., 2006). It is of note that respondents did not mention flooding more often than other extreme events, given that it is of concern for 80% of shoreline municipalities (NRCan, 2006a). Municipal and public health officials have classified flooding as one of the three primary environmental vulnerabilities of southern Quebec (Bélanger et al., 2006a). It is also of note that respondents residing south of Montreal and in Montérégie in particular did not view their region as highly vulnerable to smog, when atmospheric emissions from the two primary sources of pollution—transportation and industry—are higher there than in Montreal itself (INSPQ, 2006a, 2006c). A better understanding of the processes that influence the perceptions of ECEs and smog would be an asset to managers who deal with these issues.

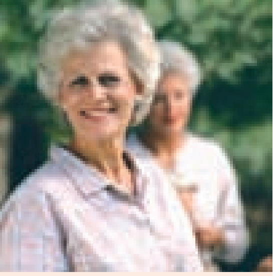
Greenhouse gas reduction and climate change adaptation strategies

Strategies related to business and industry

Implementation of the provincial government's 2006–2012 Action Plan should make it possible to positively address the concerns of the Quebec population, particularly through the consolidation of climate monitoring systems (Government of Quebec, 2006e). The systematic monitoring of environmental indicators (such as atmospheric emissions of primary pollutants) and their effects on health (INSPQ, 2006c, 2006d) is also a step in the right direction. Similar to the existing health-monitoring measures and the associated reporting required under the *Public Health Act* (Éditeur officiel du Québec, 2006c), the Ministère du Développement durable, de l'Environnement et des Parcs (Ministry of Sustainable Development, Environment and Parks) should improve current monitoring practices with respect to the state of the environment and its determinants to gain a better understanding of unfolding trends, as well as to support informed decision making at the local, regional and provincial levels (Bélanger and Gosselin, 2007). Various criteria for monitoring and reporting could be used, such as a five-year profile of environmental trends in Quebec and thematic overviews (e.g., water, air, soil) that could be updated annually. Monitoring data (e.g. health data, environmental data) should be mapped, and the maps made available on the Internet.

Land use strategies

Land use regulations related to flood plains were tightened in 2005 through the *Politique de protection des rives, du littoral et des plaines inondables* (policy on shorelines, coasts and flood plains) (Éditeur officiel du Québec, 2005b) and through the requirement to integrate risk maps into the *Municipalités régionales de comtés* (regional county municipalities) development plans under the *Loi sur l'aménagement et l'urbanisme* (Act respecting land use planning and development) (Ministère des Affaires municipales et des Régions, 2006b). The implementation of these measures—including the development of geomatics at the municipal level and the application of research findings on climate change impacts and adaptations, particularly with regard to drainage in Quebec's urban centres (Mailhot et al., 2007)—will help to characterize and reduce regional vulnerabilities. Moreover, the increased attention being paid to revegetation in urban centres and the various measures taken in this direction in recent years (e.g. inventories of municipal tree stands and various regulations) will likely bring about improvements in the management of urban forestry assets (Giguère and Gosselin, 2006d). These measures are considered as adaptations to reduce urban heat island effects. Efforts to preserve, restore or transform natural sites (e.g. beaches), as well as managed sites (e.g. parks), appear to be crucial in terms of quality of life, particularly for apartment dwellers. Apartment dwellers are more likely to seek out public places for respite during heat waves than house dwellers (Bélanger et al., 2006b).



Strategies related to infrastructures

Quebec's waste management policy for 1998 to 2008 targeted a recovery and reclamation rate of 65% (MDDEP, 1998); by 2004, a rate of 49% had already been achieved (Recyc-Québec, 2004). This environmentally sound management approach is in line with expectations in the area of recycling, and contributes to the reduction of greenhouse gases. Moreover, the initiation of a major investment cycle targeting Quebec's aging public infrastructures (e.g. viaducts, roads, water supply systems) provides an excellent opportunity to establish standards and practices that reflect the potential impacts of climate change (Bélanger et al., 2006a). Steps in this direction will generate benefits for the next 50 years, particularly in the areas of health and road safety (Canadian Automobile Association, 2006). However, far less consensus exists for other strategies, such as increasing the number of municipal pools and the number of parks with fountains, or introducing a consumption tax on water. It would seem that the first of these strategies is aimed at apartment dwellers, the underprivileged, non-drivers, and in short those least likely to have a home pool or the means to travel to recreational areas during heat waves (Bélanger et al., 2006b). A consumption tax on water finds greater acceptance among those whose ability to pay is greater (Villemaire, 1998) and among those from more populated areas where they are more likely to have been exposed to various proposals for taxing potable water.

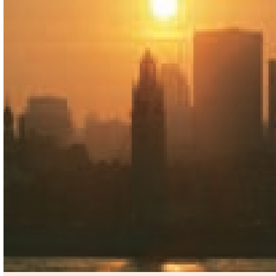
Strategies related to buildings

In the study by Bélanger and Gosselin (2007), the majority of respondents agreed on the need for air conditioning in hospitals and homes for sick persons and seniors—two groups at high risk during periods of extreme heat (Doyon et al., 2006; InVS, 2006). According to some researchers (Giguère and Gosselin, 2006d), Quebec data on air conditioning in health facilities are incomplete. Addressing this gap (including the condition of existing air conditioning and ventilation systems) would be desirable for health protection and public safety.

Those most in favour of subsidizing home air conditioning for seniors, people on low incomes and daycare centres were among the more disadvantaged respondents (many of whom lived in apartment buildings)—in other words, they were the least likely to have home air conditioning (Bélanger et al., 2006b). In 2003, for example, 15.8% of Quebec households with an income below $20,000 had air conditioning, whereas this proportion rose to 44.3% among those who had incomes of $80,000 or more (ISQ, 2006d). Such statistics argue in favour of initiatives (such as air conditioning) directed at those who are economically disadvantaged, some or many of whom are at risk of experiencing serious health problems due to extreme heat. Also, among those most in favour of air conditioning were allophones; related housing and socio-economic conditions may be an explanation (Citizenship and Immigration Canada, 2005; Leloup, 2005). Studies examining the heat adaptation strategies of various ethnic communities would be helpful to increase knowledge about health and climate change, and to optimize the support given to these communities.

The implementation of a more attractive incentive program for energy efficiency, similar to that announced in the provincial government's recent action plan on climate change (Government of Quebec, 2006e), would help to improve home insulation and facilitate adaptations to heat waves. It is hoped that measures will be introduced for persons whose dwellings require major repairs, the case for 7.8% of all private dwellings in Quebec in 2001 (INSPQ, 2006d).

The number of households that use wood burning equipment has now reached 20% (Bélanger et al., 2006c); the number of households using this form of heating increased by approximately 60% between 1987 and 2000 (MDDEP, 2006b). These are worrisome statistics from the standpoint of air quality and public health (MSSS, 2006b), particularly because close to two thirds of respondents in the study saw no reason to prohibit this type of heating during severe winter smog. Closer monitoring of residential wood burning trends and their impact on human health is in order (Bélanger et al., 2006c). Moreover, the determinants of burning wood for heat need to be identified so public awareness campaigns can be improved.



Strategies related to transportation

It is reassuring to note that the majority of respondents were in favour of measures to reduce carbon emissions, including the use of eco-friendly transportation options, the acquisition of energy-efficient cars and various other positive practices. This support should facilitate government efforts to reduce or eliminate transportation-related GHGs (Government of Quebec, 2006e), which accounted for 37.4% of all emissions in Quebec in 2003 and contributed to a host of other negative impacts, including human health impacts (Judek et al., 2005; Ontario Medical Association, 2005). Increasing public awareness of adaptation strategies to climate change constitutes a crucial step. It is very likely that those who drive a car every day will be less enthusiastic about these kinds of transportation strategies than non-drivers or occasional drivers. To optimize awareness efforts, initiatives should be undertaken to identify the primary determinants of transportation choices; to estimate the air pollution associated with each of these choices; and to evaluate people's knowledge of the link between air pollution and their transportation choices (Aubin, 2002). Few respondents were in favour of making air conditioning a standard feature in new cars. This is an encouraging sign because air conditioning consumes gas and therefore contributes to pollution (Environment Canada, 2002). Still, motor vehicle air conditioning trends should be monitored, particularly in light of the observation that people will probably travel more as the cold season grows shorter and may increase their use of air conditioning due to rising temperatures (Lafrance and Desjarlais, 2006). Only one third of respondents were in favour of air conditioning on buses. A study to elucidate the reasons for this response would be useful in developing marketing approaches to promote greater use of public transportation.

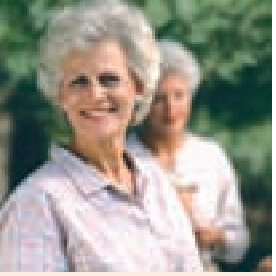
Strategies related to social measures and research

Fully 77% of respondents were in favour of providing more home services for seniors and persons with low incomes; 62% were in favour of increasing the number of homeless shelters; and 56% wanted to see more funding for research related to health and extreme climate events. In addition, 60% were in favour of adopting at least two of these three strategies—particularly women, seniors, allophones, the unemployed, the economically disadvantaged, those living alone, apartment dwellers, persons with chronic diseases and those who report their health status as poor. These are the social subgroups most likely to experience social or economic conditions that make it difficult to adapt to heat waves and extreme weather (Bélanger et al., 2006b, 2006c; InVS, 2006). Relocation is not an option for many of these people; therefore, concrete interventions should be incorporated into action plans, particularly in certain urban neighbourhoods (Laverdière, 2001).

6.5.6 Conclusion

From the community to the individual

Based on the study by Bélanger and Gosselin (2007), GHG reduction strategies that call on governments, municipalities and institutions to take action tend to find more support than those directly aimed at individuals. There may be many reasons for this. Some authors contend that the public feels powerless in the face of a global problem of this magnitude and therefore expects government and industry to find appropriate solutions (Dotto, 2000). Consequently, people feel less involved and less inclined to change their behaviour. It would seem that most people are prepared to support national and international initiatives as long as they themselves



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are not required to make significant changes in their lives (Bord and O'Connor, 1997), sacrifice their comfort for the greater good (Leiss et al., 2001), or incur costs. Finally, most people are strongly attached to the status quo, and will often do more to maintain it than they will to improve things (Rachlinski, 2000).

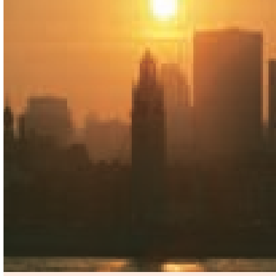
In fact, little is actually known about the cognitive processes that underlie the adoption of adaptive behaviours in social and environmental contexts that are multifaceted (everything from droughts to floods), multidimensional (from the local to the international), and characterized by multiple vulnerabilities (affecting individuals, communities and institutions). Similarly unknown is the nature of groups who prefer to maintain the status quo and of those who are unwilling to pay to effect change (Gelbspan, 2000; Sandalow and Bowles, 2001). Finding answers to these questions would surely help to advance knowledge in the area of climate change. That being said, researchers are not starting from scratch. For example, it is known that individual adaptation measures must be joined by societal and institutional changes to be effective (O'Brien et al., 2004); that sustained Canadian leadership is needed and expected to ensure that everyone is playing according to the same rules (Office of the Auditor General of Canada, 2006); and that individual contributions (e.g. behaviour, responsibility) to climate change received too little coverage in the Canadian media between 1990 and 2004 (Bouchard et al., 2005).

Because the media reinforce and amplify individual representations, Bélanger and Gosselin (2007) recommend that non-governmental organizations, researchers, journalists, municipal and public health managers—all those who have a key role to play—refocus the climate change debate on consequences, including direct and indirect costs (particularly health sector costs) (Crawford and Williams, 2006; Rittmaster et al., 2006). Such education and communication efforts could potentially generate rapid results (Kempton, 1993). In the study by Bélanger and Gosselin (2007), the respondents who were most accepting of the idea of anthropogenic causes were also more likely to support a larger number of GHG reduction and climate change adaptation strategies. Indeed, 70.4% of the respondents who felt that at least 30 of the 32 proposed strategies should be implemented also believed that human activities were causing climate change, whereas this proportion was only 28.8% among respondents who supported at most four strategies.

6.5.7 Synthesis

In industrialized countries, the heat waves of recent decades, particularly those that occurred in Chicago in 1995 and in Europe in 2003, have provided the impetus for a range of publications that have identified the segments of society most at risk in situations of extreme heat. This chapter examined how Quebeckers are adapting to heat waves. Because climate change does not necessarily occur in a linear fashion, it is important to bear in mind that Quebec will still experience very cold winters. For this reason, studies commissioned for this Assessment also examined adaptations to intense cold. Some adaptations to extreme heat and cold are designed to protect the health of the population, while others appear less effective in the long term. Many of the adaptations, some of which are both possible and desirable, are already well accepted by society while others continue to be poorly understood in terms of their link to climate change or may be unacceptable for reasons that have yet to be elucidated.

Based on the results of this study and the literature on climate change, much remains to be done to protect public health and the environment from the effects of ECEs that are likely to become more frequent and more severe. It is important to continue to monitor both impacts and better understand adaptations. The adaptation strategies proposed in this report are a step in the right direction.



6.6 PERCEPTIONS OF MUNICIPAL AND PUBLIC HEALTH MANAGERS

6.6.1 Introduction

By the end of the 1990s, municipal managers in Canada had indicated their concerns about climatic changes (Municipalities Issue Table (MIT), 1998) and proposed measures to reduce GHG emissions in partnership with all levels of government, the private sector and volunteer organizations (MIT, 1998). The following sectors of concern were identified: water supply, waste management, transport, operation of municipal equipment and facilities (e.g. recreational equipment, social housing), energy consumption and GHG emissions (e.g. municipal regulations, urban planning, zoning standards, public relations). Between 100 and 200 of the approximately 4,000 incorporated Canadian municipalities (in about the year 2000) were able to respond to ECE events (MIT, 1998). The Green Municipal Fund, created by the federal government and managed by the Federation of Canadian Municipalities, has supported some 350 projects[19] since 2000 (Federation of Canadian Municipalities, 2006), whereas there are currently 3,700 municipalities across the country according to the Federation. Findings in Quebec are similar; only 93 of 1,110 municipalities[20] (Ministère des Affaires municipales et des Régions (MAMR), 2005c) are registered with the GES Énergie program (Government of Quebec, 2000, 2005b).

In terms of public health, the Climate Change and Impacts Adaptation Programme has funded only 13 research projects relating to health impacts and human adaptation since 1998 (Government of Canada, 2005). In Quebec, MSSS did not join the Ouranos Consortium until 2004. In 2002, very few public health professionals were concerned with climate change (Bélanger et al., 2002). In southern Quebec, interest was piqued by the 2003 heat wave in France, essentially to implement emergency measures for extreme heat (Giguère, 2005).

It is unlikely that the lack of awareness of the issue or general information is a key factor in the reluctance of municipal and public health managers to be involved in climate change issues. In fact, the media have widely broadcasted climate change information in recent years, particularly because of the Kyoto Protocol. Several synthesis documents (including some available on the Internet) have also been developed for managers (Isuma, 2001; Auger and Kosatsky, 2002; Gosselin and Grondin, 2002; Ouranos, 2004) and are widely available in various publications and on Quebec and Canadian government web sites. Consequently, other factors more incisive than awareness and general knowledge of climate change would influence public managers in their decisions whether or not to act on this issue, such as the degree of concern regarding such occurrences in their areas, various conditions facilitating or hindering action (MIT, 1998; Canadian Public Health Association (CPHA), 2001), as well as the degree of involvement by partners (Azzah et al., 2002; Wittrock et al., 2001) and the community (MIT, 1999; CPHA, 2001). To facilitate communication and collaboration in Quebec between municipal and public health managers, both of whom are involved in managing the causes and effects of climate change, a better understanding of their respective perceptions was deemed necessary.

Highlights of a study conducted in 2005 among municipal and public health managers in southern Quebec are presented here. The study investigated the relationship between managers' concerns about climate change and its effects and their perceptions of the importance of planning mitigation and/or adaptation measures to be taken over the next 10 or 20 years (Bélanger et al., 2006a) (Figure 6.23).

19 Examples: feasibility studies, pilot projects, field tests.

20 As of January 1, 2005, prior to reconstitution and pursuant to the decree of December 2004, there were 1,110 municipalities in Quebec, excluding Aboriginal reserves, federal land, unorganized territories and Inuit land. That number increased to 1,141 as of January 1, 2006, with reconstitution.

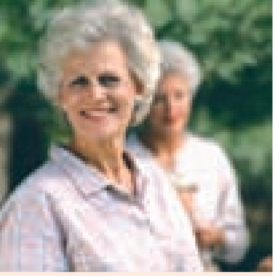
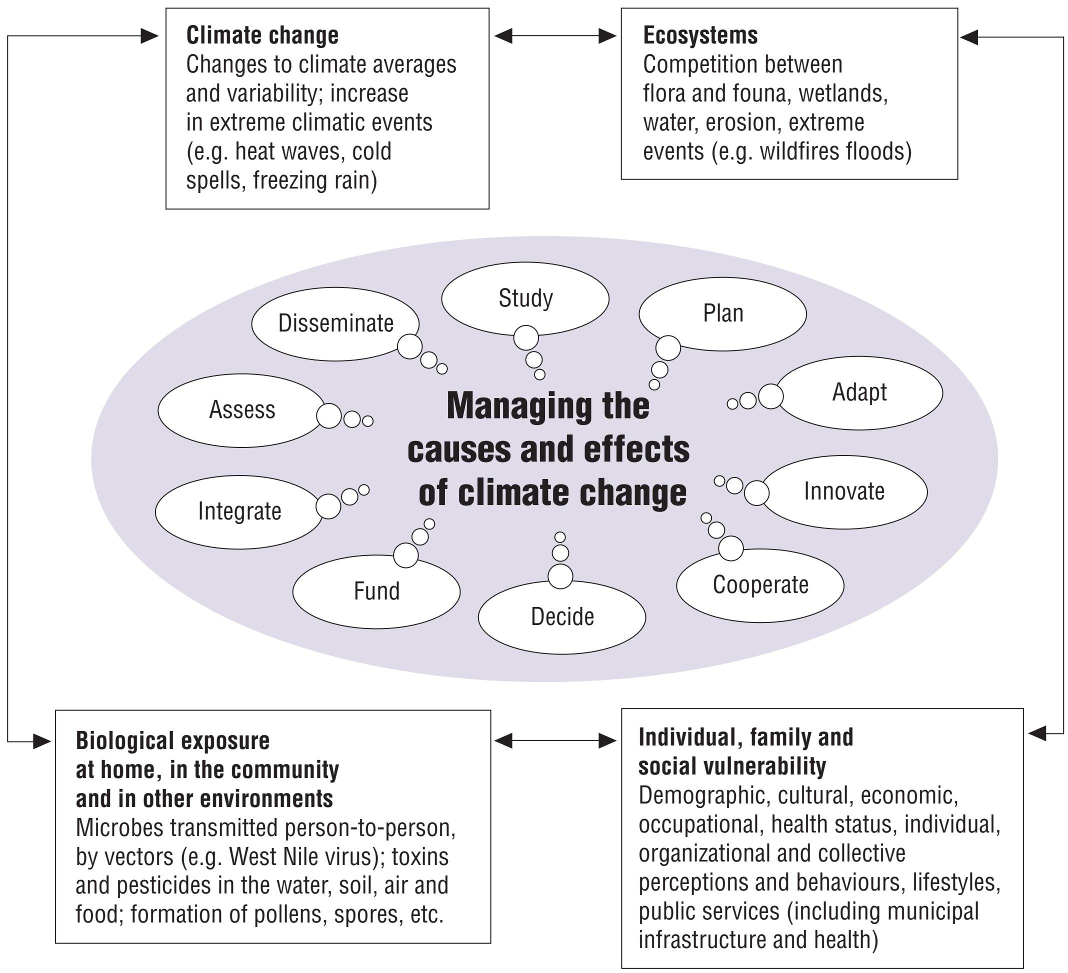


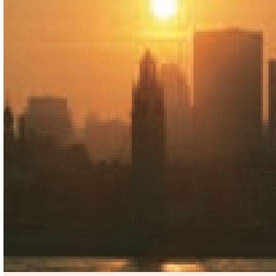
Figure 6.23 Managing the causes and effects of climate change



Source: Adapted from models presented by WHO and the National Institutes of Health (NIH) Committee on Climate, Ecosystems, Infectious Diseases and Human Health, 2001; WHO, 2001; WHO and European Environment Agency, 2002).

In the context of organizational learning theory (Tebourbi, 2000; Berkhout et al., 2004), the study findings provided some answers to the following questions:

- What socio-economic groups of people in their cities, municipalities or socio-health regions do managers see as most vulnerable to climate change, in terms of health and the environment?
- How do managers perceive the frequency and severity of climate change in their regions and in the province? Are they concerned?
- What regional effects of climate change are of concern to managers, particularly in terms of health, civil security, the built or natural environment, infrastructure and the economy?
- How do managers perceive the need to implement, in their respective regions, specific programs in relation to climate change? Why are these programs necessary?
- What actions do they feel have already been taken in their regions to deal with climate change? What key stakeholders are currently involved in this area—locally, regionally and/or nationally—or could possibly be involved?



6.6.2 Methodology

The study (Bélanger et al., 2006a) dealt with municipal and public health managers in southern Quebec, representing more than 99% of the Quebec population (ISQ, 2000). It dealt particularly with 15 of the 18 socio-health regions (Figure 6.12: excluding regions 10, 17 and 18). Each of these health regions is served by a regional health and social services agency which has been responsible for ensuring the delivery of local services since 2003 (Éditeur officiel du Québec, 2005a). Each regional agency has a public health director—who works in close cooperation with other institutional partners in the region (e.g. hospitals)—as well as emergency measures, occupational health, environmental health and infectious disease officials. Each of these professional groups plays a key role in the climate change file (Cassel, 1990; Royal Society of Canada, 1995; Patz et al., 2000; Warren et al., 2004), due to the diversity of clients that may be affected by climate change (e.g. seniors or the chronically ill) and the scope of these health effects (e.g. social and mental stresses caused by catastrophes, heat stroke in workers, water and food contamination) (Warren et al., 2004).

In 2005, there were 86 municipalités régionales de comté (MRC) (regional municipalities) in Quebec, as well as 14 cities (including nine with more than 100,000 residents) that were not in a regional municipality but exercised some of their authority (MAMR, 2005c). Forty municipalities were used for the study. This choice was made to reflect the variability of weather in southern Quebec, in coastal regions (e.g. sea level rises), agricultural regions (e.g. drought), forests (e.g. wildfires), tourist areas (e.g. erosion of beaches, less snow and skiing) and urban areas (e.g. heat islands) (Warren et al., 2004). All of the municipalities managed files related to the effects of climate change, in particular those relating to development, urban planning and agricultural land (e.g. plans, regulations); civil security; services and infrastructure (e.g. housing, roads, mass transit, waterworks, sewers); culture, recreation and tourism; communications and public relations; and administration (e.g. economic development).

A total of 70 health managers and 84 municipal managers were asked to take part in the study. The response rate was 84.4% (58 health managers, 72 municipal managers); more than two thirds of the respondents had at least 10 years of experience as managers. The interview questionnaire was based on health and climate change literature (MIT, 1998; CPHA 2001; Fishbein et al., 2001; Wittrock et al., 2001; Federation of Canadian Municipalities, 2002; Academy for Educational Development, 2003). To better examine the perceptions of managers, these key variables referred to various psycho-social theories rather than a single one. The contents and validation procedures are set forth in Bélanger et al. (2006a).

Three interviewers conducted the data collection by telephone (39 minutes average duration, by appointment) from May 16 to July 8, 2005. The content of the interviews was coded using N'Vivo software (Gibbs, 2002; Quality Systems Registrars, 2005). Two-way interaction between the coder and the researchers or interviewers allowed progressive validation of grouping the data into intermediate response categories (e.g. water management: potable water, wastewater, recreational water) and preliminary descriptive generalizations (Huberman and Miles, 1991; Erlandson et al., 1993). Finally, the thematic content (Paillé and Mucchielli, 2003) was analyzed based on the following five criteria: internal homogeneity (consistent within a single category), external heterogeneity (mutually exclusive or clearly different categories), relevance and comprehensiveness of data, and explanatory productivity (construction of a logical chain of indications and evidence to support the result observed) (Patton, 1990).

The second stage of the analysis was based on a theoretical organizational learning cycle (Tebourbi, 2000; Berkhout et al., 2004) (Figure 6.24). The learning cycle outlines the processes that can help an organization learn from its experiences, guide its objectives and select the relevant information (including the consideration of social, political and structural factors) needed to resolve its problems (Tebourbi, 2000). The processes assist in the interpretation and communication of decision-making knowledge, including the formal and informal mechanisms, used in management and planning.

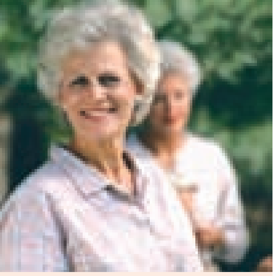
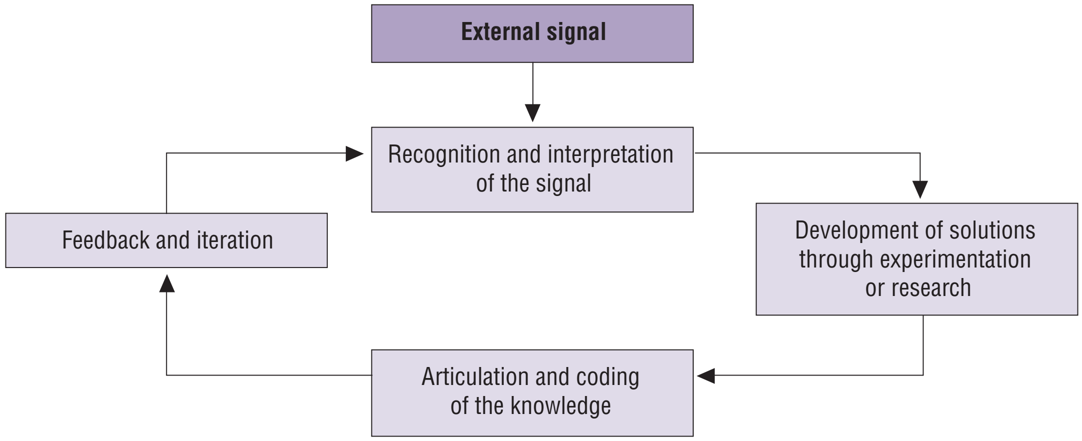


Figure 6.24 Learning cycle



Source: Adapted from Tebourbi, 2000 (Figure 8, p. 71) and Berkhout et al., 2004 (Figure 1, p. 9).

6.6.3 Results

All respondents (municipal and health managers) perceived vulnerabilities in their regions, whether environmental, socio-economic or health-related. All also reported regional impacts, as a result of climate change, on the general population or more vulnerable subgroups, on natural or built environments, on recreational, sporting or tourism activities, and on the economy (Table 6.6).

Table 6.6 Distribution of managers, by number and percent, and the impacts of climate change on public health in their regions, by category

Impacts of climate change	Health managers	Municipal managers	Number of respondents interviewed
Total number of respondents interviewed regarding climate change impacts on public health	51 (100%)	69 (100%)	120 (100%)
Negative impacts on public health in general	*48 (94%)*	*62 (90%)*	*110 (92%)*
Negative impacts on general health	47 (92%)	57 (83%)	104 (87%)
Negative impacts on physical health	38 (75%)	33 (48%)	71 (59%)
Respiratory and allergies	17 (33%)	16 (23%)	33 (28%)
Infectious diseases	16 (31%)	6 (9%)	22 (18%)
Water-borne diseases	15 (29%)	6 (9%)	21 (18%)
Enteric diseases	9 (18%)	1 (1%)	10 (8%)
Cancers	4	6	10 (8%)
Deaths	5	4	9 (8%)
Other impacts on physical health[i]	7	4	11
Impacts on mental health	13 (25%)	16 (23%)	29 (24%)
Moral	3 (6%)	7 (10%)	10 (8%)
Stress	2	5	7 (6%)

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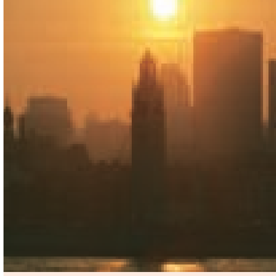

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Impacts of climate change	Health managers	Municipal managers	Number of respondents interviewed
Increased vulnerability	2	3	5 (4%)
Other mental health problems[ii]	7	6	13
Causes of impacts on health	*27 (53%)*	*24 (35%)*	*51 (43%)*
Heat/smog	15 (29%)	11 (16%)	26 (22%)
Water quality	11 (22%)	6 (9%)	17 (14%)
Floods and landslides	2	3	5 (4%)
Other causes[iii]	3	8	11
Variable impact	*2 (4%)*	*5 (7%)*	*7 (6%)*
Little impact on general population	*4 (8%)*	*3 (4%)*	*7 (6%)*
Other (habits and quality of life)	7 (14%)	3 (4%)	10 (8%)
Positive impacts	2	2	4 (3%)
Unknown	2	1	3 (3%)
No impact on public health in general	*5 (10%)*	*12 (17%)*	*17 (14%)*

Notes: As one respondent may identify more than one impact, the total number of respondents does not correspond to the total respondents by category or subcategory.

i Other impacts on physical health: obstacles to physical activity, dehydration/heat stroke, accidents, high blood pressure and cardiac problems, chilblains, illnesses of unknown origin, respiratory problems.

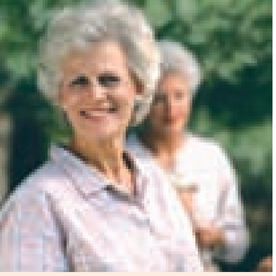
ii Other mental health problems : poverty, depression, passive-aggressive behaviour, post-traumatic stress, suicide.

iii Other causes: pollution, tornadoes, winter temperature fluctuations, snowstorms, forest fires, acclimitization, cold, lack of information.

Source: Bélanger et al., 2006a.

At the regional level, most managers felt that average annual temperatures had risen noticeably over the past few years. They also felt that winters were not as harsh as they were in the past, winter rains and fluctuations in temperature were more common, and snowstorms and the amount of snow on the ground had decreased. Increases in the frequency and violence of climatic events were more commonly noted than rises in temperature. Reference was often made to events that occurred during the summer and winter, particularly heat waves and cold snaps, heavy rainfalls or freezing rain (including their effects, such as flooding), and large variations in temperature. At the provincial level, perceptions of these climatic events were generally the same as those regionally. A majority of respondents felt that climatic events could be accelerated by certain human activities, though not all were convinced that the climatic events they perceived were due to climate change, nor did they did directly relate their observations to ECEs that had occurred in recent decades in their regions or in the province.

Most municipal and health managers were concerned about the regional and provincial impacts of climate change over periods of 10 and 20 years. Similarly, most managers identified the need over the next decade to implement intervention programs related to the effects of climate change. However, regional emergency measures aimed at adapting to these effects have been relatively modest to date, are not uniform provincially, and mostly deal with heat waves. Some respondents noted that the responsibility for and the management of climate change files should rest primarily with regional municipal health officials rather than with various organizational levels, as is the current situation.



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The following obstacles to facilitating the implementation of intervention strategies were noted:

- ambiguous messages from upper levels of government decision makers;
- lack of a mandate defining the respective responsibilities and roles of decision makers; and
- lack of financial and technical support, particularly for small and medium-sized municipalities, to implement measures for mitigating and adapting to the effects of climate change.

6.6.4 Discussion

6.6.4.1 Rising average temperature in winter

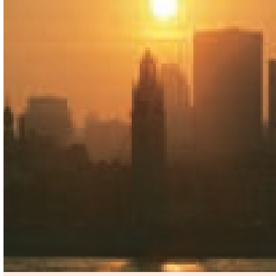
The perception of municipal and health managers that average annual temperatures had not risen noticeably over the last few decades on a regional basis and, to an even lesser degree provincially, may be due to the microclimates of southern Quebec. These microclimates may contribute to a reduced ability to detect "annual" variations that have fluctuated from only 0.5 to 1.2°C between 1960 and 2003 on an east-west trajectory (Yagouti et al., 2006). Furthermore, warming is not necessarily linear (MacCracken et al., 2001). Compared with annual warming, the average rise in temperature in the winter, which is corroborated in the literature (Warren et al., 2004), was most often reported by managers.

6.6.4.2 Increased extreme climate events in summer and winter

The increased frequency and violence of climatic events had more consensus than increased average temperatures, both regionally and provincially. No region was exempt: only the type of events differed, based on the geomorphic characteristics of the area (e.g. strong winds and erosion of shores in the east of the province, tornadoes and violent storms in the west). Some climatic events were mentioned more frequently, such as heat waves, major fluctuations in temperature, heavy rainfalls causing floods and ice storms. Overall, the incidence of these events worries much of the Quebec population, particularly the many summer floods that have affected more than 80% of shoreline communities (NRCan, 2006a). The public has also been affected by ECEs covered widely by the media, including heat waves and various catastrophes over the last 10 years, in particular the Saguenay flood in 1996 (Warren et al., 2004), the Ice Storm in 1998 and the numerous wildfires caused by lightning in the summer of 2002 (NRCan, 2002).

6.6.4.3 Contribution of human-made causes to climate change

Recent global warming of 0.5°C can be partially attributed to GHG emissions generated by human activity (IPCC, 2007). Many managers seemed to be fully convinced of this, some agreed but were not fully convinced of a direct connection, and some did not agree at all. Some respondents appeared to have been influenced by the controversial media coverage of this issue over the last few years (Villeneuve and Richard, 2001). The lack of clarity in the debate on the causes of climate change is not without consequence; first, because decreasing the emission of GHGs associated with human activities is important in reducing the rate and extent of climate change (Warren et al., 2004); second, because this lack of clarity can affect the decision-making process (Prochaska et al., 1995) by influencing the pace at which changes in managers' behaviour take place—from denying the contribution of human-made causes, to "reacting" to climatic events when they occur and, then, to being "proactive" with regards to both GHG emissions and the development of adaptation measures.



6.6.4.4 Certainty about the reality of climate change

Not all managers were certain that they were observing a period of climatic change. It is difficult to categorically state that changes already exist, and the controversy surrounding the causes of climate change may have influenced the perception of some managers. Various factors related to the organization with which they were affiliated may also have contributed; municipal managers seem somewhat less convinced of the reality of climate change than health managers.

The sources of information preferred by municipal and health managers may have had an influence on their different perceptions of the reality of climate change (Tebourbi, 2000). Municipal managers primarily consult publications from government departments and agencies, and economic development organizations[21] (Ippersiel and Morissette, 2004) (i.e. a more general literature focusing on the impacts on infrastructure or territory (MAMR, 2005b)), while health managers usually refer to the scientific literature on the relationships between certain risk factors (e.g. climatic variables) and morbidity and/or mortality (e.g. Patz et al., 2005; McMichael et al., 2006).

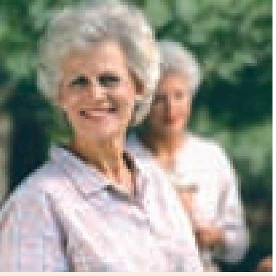
The perception that climate change is in progress also has different implications for managerial practices. In the municipal sector, the formal development of numerous procedures and regulations specify what is to be done and how it will be done, and directives specify how to proceed (Tebourbi, 2000). Legislation, policies and best practice guides often direct the actions of municipal managers. Consequently, the information related to climate change must be perceived (and then integrated) as being sufficiently strong, foreseeable and reliable to justify the implementation of the procedures and regulations. The same is not true for public health managers; the system allows for greater ambiguity or uncertainty, particularly because it is mandated to protect public health from risks that may be incurred, even in the absence of irrefutable evidence (the precautionary principle) (Chevalier et al., 2003).

6.6.4.5 Concerns about climate change

Most managers were concerned about climate change over a period of 10 years and others, with some exceptions, over a period of 20 years. The main concern, regionally and provincially, related to the health impacts of climate change. Some managers indicated the need to improve public awareness. Few managers commented on actions that had been taken; the small budgets allocated to this area are probably instrumental in this regard.

According to Bélanger et al. (2006a), no data are available on the portion of public sector (federal, provincial and municipal) budgets in Canada or Quebec that are allocated specifically to preventative environmental activities or preventative public protection purposes. No category other than the allocation of public funds for pollution prevention exists (Statistics Canada, 2000). This category included expenditures for such activities as drinking water supply and purification; waste removal and destruction (and recycling); and other expenses, such as soil decontamination, atmospheric pollution, environmental assessments and administration of environment departments. This publication is currently being revised, but the numbers have probably remained similar (i.e. approximately 4.5% of the total public sector budget allocated to all of these activities, which are only partially or not at all of a preventative nature). Of these expenditures, totalling approximately $10 billion, 66% was assumed by municipal administrations, approximately 21% by the provinces and approximately 13% by the federal government. Allocation by province was not presented, but it can be assumed that this proportion also applies to Quebec.

21 This observation is likely. According to Ippersiel and Morissette (2004), the five main sources of information that municipalities in Quebec consult or would consult are: (1) government departments and agencies and their publications; (2) economic development organizations and their publications; (3) seminars, conferences and fairs; (4) associations or non-profit organizations and their publications; and (5) specialized publications and print media.



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The situation is clearer for the health sector. In 2005, approximately $8 billion or 5.6% of public sector budgets was allocated to preventative public health activities (Canadian Institute for Health Information, 2005). The vast range of such activities covers all areas of health, including food and drug safety; health and environmental inspections; health promotion activities; community mental health programs; public health nursing services; measures to prevent the spread of infectious diseases; and measures to promote and improve workplace health and safety in public agencies. A breakdown of expenditures by province was not possible. Specific data for Quebec for these types of expenditures are not available either from ISQ or MSSS. It is assumed here, given the lack of information, that proportions (5.6%) are similar in Quebec and the rest of Canada

6.6.4.6 Regional impacts of climate change

All municipal and health managers reported that climate change could have regional impacts on the general public; more vulnerable subgroups; natural and/or built environments; recreational, sports and tourism activities; and/or the economy. Generally, the climatic impacts perceived by respondents referred to regional vulnerabilities that they saw as already existing, whether environmental, socio-economic or health-related. Overall, however, the impacts and vulnerabilities most indicated by municipal managers differed from those of health managers. This is partially attributable to their respective duties and the legislative framework within which they work.

Municipal managers must ensure that municipal services meet the diverse needs of the community or region, particularly from the perspective of socio-economic development (especially among elected officials) while taking into account an aging population, major environmental issues and the globalization of markets (Soucy, 2002). A considerable number of laws and regulations govern the activities of these managers, including the *Municipal Powers Act* (e.g. water management, transportation) (MAMR, 2006c), the *Land Use Planning and Development Act* (e.g. planting and cutting trees, shared agricultural use, erosion and flooding) (MAMR, 2006b), the *Environment Quality Act* (e.g. waste management) (Éditeur Officiel du Québec, 2006a), the *Act to amend various legislative provisions concerning municipal affairs* (e.g. hog farming) (MAMR, 2006a), the *Civil Protection Act* (e.g. civil protection) (MSP, 2005), and the *Municipal Code of Quebec* (e.g. housing) (Éditeur officiel du Québec, 2006b).

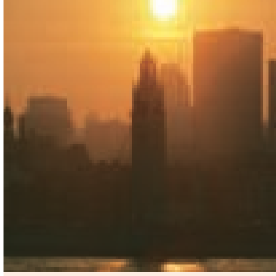
Public health managers are mainly accountable under the *Public Health Act* (Éditeur officiel du Québec, 2006c) to protect, maintain or enhance public health and well-being. Their focus is on a range of illnesses—their causes, prevention and treatment—and the related risk factors, including pollution and environmental phenomena.

6.6.4.7 Need to implement regional programs specific to climate change

Some respondents felt there was a need to implement regional programs specific to the effects of climate change over a period of 10 years. To date, very few measures have been developed and those that have deal mainly with heat waves.

Decision makers in southern Quebec were greatly influenced by the heat wave in France in 2003 (Giguère, 2005). This highly publicized heat wave demonstrated that some members of the general public—particularly seniors and the socially or economically disadvantaged—can die from heat. It also underscored the need to take quick political and administrative action; to do so, however, first the actions to be taken must be completely planned. Thus, plans were developed throughout the province to mitigate the negative effects of heat waves, particularly for major urban centres (Giguère and Gosselin, 2006d).

On the other hand, although heavy rains and their impacts on waterways, wastewater and drinking water were often mentioned by municipal and health managers, few indicated they had taken relevant action to include considerations of the effects of climate change. However, flooding affects 80% of shoreline communities in Quebec (including Montreal and Quebec City) and, on average, costs an estimated $10 to $15 billion per year (NRCan, 2006a). They are, in fact, the most commonly occuring natural disaster and the consequences of which can be major, as illustrated by the Saguenay flood in 1996 (Warren et al., 2004). Despite the observed increase in ECEs over the last 15 to 20 years, the evidence does not seem to be enough to motivate immediate implementation of adaptation programs integrating climate change considerations. A similar situation applies to the road networks that are perceived as highly vulnerable, due to increasingly common sudden temperature changes in the winter possibly resulting in rains, flooding and damaged infrastructure (NRCan, 2006a).

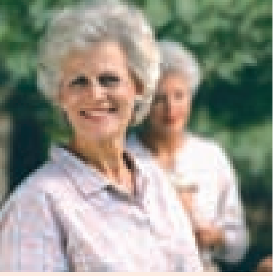


The question that arises relates to the mandate of managers to implement regional programs to better manage the effects of climate variability and long-term climatic change. According to some managers, responsibility in this area falls to federal and provincial levels of government, and to municipal organizations and public health branches. Some managers also felt involved, given their respective duties. However, for authorities to become involved, their mandates in this area must be clear and precise; this does not seem to be the case. For example, the guide to develop an action plan for the renewal of drinking water and sewer lines, developed in October 2005 (MAMR, 2005a), referred only to the numerous downstream factors in this process (e.g. ability to pay, opportunity costs, discounted costs based on the funding rate). A federal and provincial mandate to adapt to climate change would have provided the necessary incentive and direction to also consider possible upstream factors, including climatic factors such as heavy rains and flooding.

To date, political consideration of climate change seems centred on GHG emissions and associated rising temperatures, including heat waves. However, increases in flooding and snowstorms are serious climate change concerns (Warren et al., 2004). In Quebec, they are also much more common and widespread than heat waves and have a major impact on public health and well-being, and the economy.

Public service organizations in Quebec place more importance on organizational innovation than on technological innovation (Ippersiel and Morissette, 2004). The lack of capital and qualified personnel for developing and using new technologies might delay some decisions, but it would be likely that managers and the public would be not be interested in investing in such innovations, even if the necessary funds were available. There could be greater publicity and better use of various existing "no regrets"[22] measures that are perceived by managers as being already effective and not necessarily innovative: for example, the construction of dykes, retention ponds and highway diversions; development of mass transit and cycling paths; construction away from flood zones; public health surveillance systems; public health emergency measures training and simulation; and programs on daily life and domestic life aids offered by MSSS.

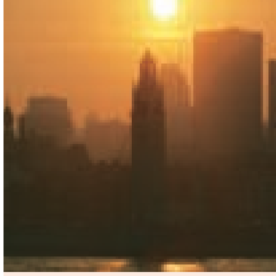
22 No regrets measures are those for which benefits, such as energy savings and reduced pollution, at least equal their costs to society, regardless of the benefits stemming from the mitigation of the effects of climate change.



Budget constraints were also mentioned by managers. Even "no regrets" measures incur direct costs (e.g. specialized equipment for clearing icy roads in the winter) and indirect costs (e.g. personnel). The amalgamation of municipalities could facilitate the implementation of certain strategies for adapting to the effects of climate change (e.g. pooling of specialized material and human resources) that exceed the financial capacity of many smaller municipalities. For instance, the additional cost of building all-season roads (other than on permafrost) and bridges was estimated, respectively, at $85,000 per kilometre and between $65,000 and $150,000 per bridge (in 2001 dollars), for average increases of 5% in temperature and 10% in precipitation in this century (Dore and Burton, 2004). However, it is unlikely that amalgamations will remedy all regional program issues, such as the problems inherent in interaction between numerous stakeholders during a disaster (e.g. values, training, varying procedures). With respect to technological innovation, public services in Quebec rarely have access to funds for such development or to encourage innovators (Ippersiel and Morissette, 2004). As early as 1999, the Municipalities Issue Table (MIT) noted limited access to capital and limited experience with external capital sources in relation to the funding of energy savings or GHG emissions reduction programs (MIT, 1998). In the area of public health, it is primarily research funds that permit the exploration of new technology and innovation (Bédard et al., 2003).

Unlike federal and provincial government managers often working at macro policy levels, regional and municipal managers are responsible for implementing in the field and managing programs specifically related to climate change in their areas. Managers identified municipal branches and their land use and urban planning services, public health branches and environmental health teams, as possible key players in dealing with the effects of climate change. They also remarked that the support of colleagues, leaders (elected officials) and the public was insufficient. This adds to the difficulties faced particularly by municipal managers who must ensure that actions taken are approved by the public (Ippersiel and Morissette, 2004) and contribute to improving the services already offered, while reconciling economic constraints (Soucy, 2002). Even with popular support for a large number of adaptations, managers have many other considerations. For example, public health managers must work in close cooperation with other institutional partners in the region (e.g. hospitals), which have priorities other than climate change and are not necessarily convinced of its impact on health care services because its impacts on health are not yet readily observable (McMichael et al., 2006).

Bélanger et al. (2006a) suggested it would be highly desirable to add a component on reducing existing vulnerabilities to those actions targeted at mitigating GHGs and adapting to climate change. This would facilitate viewing vulnerability not as the net result of climate change once the adaptations are in place, but as a characteristic (such as available income) or a condition (such as being disabled) generated by various social and environmental processes and exacerbated by climate change (O'Brien et al., 2004). In their opinion, this approach would solidify the integration of this "human" dimension as the cornerstone of the entire process to address climate change.



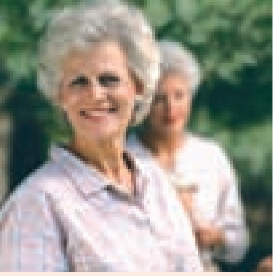
6.6.4.8 Comments on the validity and reliability of results

In this research, the rate of participation was 84.4% (n=130). Managers from various activity sectors of public and regional interest were interviewed in the 15 socio-health regions in southern Quebec to reflect the variability of climate impact in coastal, agricultural, forestry, tourist and urban areas. Respondents included public health directors, emergency measures officials, occupational health officials, environmental health officials and infectious disease officials from health and social services agencies in each of the 15 regions. They also included municipal managers from 40 of the 86 municipalités régionales de comtés (MRC) and 14 cities that would be concerned with land-use planning (including agricultural), civil protection, services and infrastructure, culture, recreation and tourism, communications and public relations, and administration. This sample includes managers who play key roles in the area of climate change in the various sectors of southern Quebec's 15 regions.

Consideration was given to whether some managers answered the questions so that their statements would be in keeping with media coverage on climate change, particularly in the context of debates over the Kyoto Protocol (Paulhus, 1991). However, Bélanger et al. (2006c) believe that the influence of media coverage in favour of ratifying the Kyoto Protocol in Quebec has had little influence on the data for the following reasons. First, distribution of responses covered a wide range of possibilities (e.g. from completely "for" to completely "against" the idea that climate change is a reality). Second, some managers did not hesitate to indicate their scepticism about the actual reality of climate change. Before the interviews were concluded, views on the reality of climate change were confirmed and, if needed, responses were clarified.

It is possible that one-on-one interviews, or longer telephone interviews, would have allowed for a more detailed response to certain questionnaire topics, such as existing vulnerabilities or obstacles to the implementation of specific climate change programs. However, this is highly unlikely for the following reasons. During data collection, the information provided a diminishing return and the data saturated (which means that little or no new information showed up from interviewees after the initial period, a methodological criterion used to assess a qualitative survey's validity) (Deslauriers, 1991). In addition, although increased ECEs were noted as significant, as was the rise in winter temperature (based on certain climatic indicators, such as rain, snow cover), few managers considered this information as significant and sufficiently predictable to include climate change issues in their agendas. Apart from heat wave plans, very few new measures are currently in place to systematically mitigate or counter the impacts of climate change.

This situation is not surprising (Berkhout et al., 2004). Evidence of climate change is not readily apparent because the signal of such change is "muddied" by natural climate variability (increased frequency and severity of existing situations). In addition, the interpretation of that signal depends on specialists outside the organizations with which managers are associated, and these specialists use complex mathematical modelling that is not familiar to managers. At this stage of evolving knowledge, the specialists (scientists) cannot provide, with absolute certainty, exact responses to crucial questions managers would ask about the scope and timing of climate changes. Therefore, it is difficult for municipal and health managers to translate the signals of climate change into concrete action.



6.6.5 Synthesis

Based on the preceding findings, Bélanger et al. (2006a) inquired if immediate action on climate change was possible—considering that currently the scope of its effects is more expected than experienced, and its effects will be most evident in populations that for various other reasons are already vulnerable. In an affirmative response, they put forward a "no regrets" intervention strategy, adapted for use by municipalities and public health agencies. It integrates various proven methods for preventing the negative effects of climate change and includes the following five components.

1. Clarify the mandate for consideration of climate change

Federal and provincial levels of government must present a clear, consistent message about climate change, including a clear definition of the mandates and roles of the parties involved in addressing this issue. According to interviewees, this is necessary for municipal and public health managers to feel that they can proceed with implementing concrete measures and, as required, start internal processes to develop innovative responses. To support managers, this message should likely be in the form of a legal obligation to consider the risks of climate change in the decision-making processes of health and social services agencies, municipalities and provincial departments.

2. Benefit from the present cycle of investment in public infrastructure

Under the present cycle of investment in public infrastructure, standards and practices that reflect the possible impact of climate change should be adopted. Several adaptations to climate change would involve improvements to infrastructures, often those with a life span of 30 to 50 years (e.g. water treatment plants, buildings, roads). A cycle of major investment in Canada is beginning as a result of aging infrastructures, many having been constructed more than 40 years ago. Great opportunities are available at this time for action in the area of climate change, at minimal additional cost. Taking this opportunity will have beneficial effects for the next 50 years.

3. Support strengthened standards, procedures and organizational routines

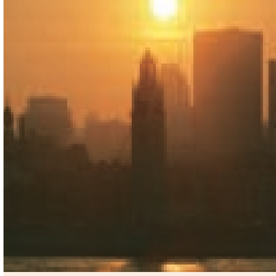
Standards, procedures and organizational routines should be strengthened, particularly by implementing training to develop skills (e.g. risk assessment, including maps of risk areas), developing intervention protocols or structured guides that are easy to use, and creating ad hoc provincial committees with various experts and managers with field experience who can provide technical assistance to disadvantaged areas facing uncommon situations.

4. Transfer and share knowledge more effectively

Knowledge about R&D activities, particularly those undertaken to date within Ouranos, should become more widely available. This transfer of knowledge would facilitate decision making and the definition of standards and procedures that could be used locally by organizations and municipalities throughout Quebec. This approach would help to remove the "high-tech cloud" that seems to surround the climate sciences in the minds of managers. Some adaptations to climate change have already been implemented by local authorities as local and regional interventions to address issues other than climate change. The knowledge gained by sharing "know-how" in this area could be a significant asset for those who do not have the expertise or resources to implement climate change adaptations.

5. Raise public awareness of climate change

The public and elected officials must be aware of current and future climate change issues so that initiatives taken by managers receive timely support. A structured, long-term program to raise public awareness would be a valuable contribution to taking action on climate change.



6.7 CONCLUSION

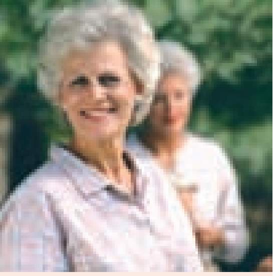
The first *Canada Country Study: Climate Impacts and Adaptation* (Bergeron et al., 1997) included a chapter on Quebec, which incorporated a health component. The report concluded that information on impacts and adaptations about health and the effects of climate change were poor or sketchy. Several recommendations were made, the first being:

> "Initiate multidisciplinary studies to quantitatively assess the direct impacts of oppressive heat waves, intense cold waves and winter storms on morbidity and human mortality and on the social behaviour of people living in urban and semi-urban environments in Quebec." (p. 196)

It has taken almost 10 years since the study to implement this recommendation; the summary results are presented in this chapter in brief. Since the study, the base of scientific knowledge in Quebec has grown significantly, and the understanding of climate change issues in Canada and globally has evolved. Therefore, the expected scope of certain effects can be estimated, and preparations for the required adaptations can be made immediately.

With regard to southern Quebec, these effects are likely to have a negative effect on health; the effects appear be major in scope, if judged by the simulated future deaths presented here. In absolute number of deaths per year, there would be an increase of 150 deaths per year by 2020, 550 annual deaths by 2050 and 1,400 by 2080 in southern Quebec. This is likely a lower value, considering the range of expected impacts. The simulations do not take into account the fact that the Quebec population will age considerably during that period; the percentage of people aged 65 and over (who are much more sensitive to climate variations) will more than double during that period. These estimates also do not include increases in mortality from extreme weathers events such as heat waves or storms, or a possible future outbreak of water-, vector- or food-borne infectious diseases. Other illnesses related to climate change have not yet been accounted for. It is predicted that the general health of the population could further deteriorate; for example, the current epidemic of obesity and diabetes—conditions that increase vulnerability to the effects of climate change—could also complicate this picture over 20 or 30 years. These simulations also assume that GHGs will be stabilized at twice the current level, which may be considered optimistic. Important impacts are also expected in Quebec's northern regions; these are presented in Chapter 7, Health Impacts of Climate Change in Canada's North.

In comparison with the preceding estimates of mortality, traffic accidents kill some 700 people a year in Quebec, while approximately 6,000 are seriously injured (Société de l'assurance automobile du Québec, 2006). Major programs are directed toward prevention of traffic accidents and the mitigation of their consequences, and the costs of these accidents to society are hundreds of millions of dollars each year (Société de l'assurance automobile du Québec, 2006). The negative health effects of climate change are not yet of the same scope, but could be in 30 or 40 years according to the simulations, or possibly earlier.



The good news is that much of the expected effects can be minimized and even prevented. Just as traffic injuries have fallen by 60% over 25 years because of effective awareness and prevention programs directed to the public and involving institutions across all sectors, it is possible to act as effectively with regard to the effects of climate change. This chapter has outlined a number of opportunities and examples that can be supported and reinforced that confirm that Quebec has many of the tools and means to undertake such a challenge.

The other good news is that Quebec has begun to take action in the last few years in certain areas that will be useful in adapting to climate change. The provincial 2006–2012 action plan on climate change (Government of Quebec, 2006e) and most of its planned measures are generally supported by the population. These province-wide measures include the northern regions where the majority of Aboriginal and Inuit populations reside.

The research results and recommendations emanating from the research projects commissioned for this Assessment and reported in this chapter have already helped to raise awareness among health officials in Quebec about the need to implement concrete measures. The importance of the health research program (and the dissemination of this research) for the period 2006 to 2009 supported by Ouranos with INSPQ, MSSS, Health Canada, Environment Canada and university researchers must be noted. Some significant measures to reinforce health surveillance during ECEs and heat waves are also planned for this same period. A program for promoting cool islands in urban areas has also been announced, as have efforts to upgrade ventilation and air conditioning in health care establishments. Finally, a program to train health care providers is planned. Under the safety of people and property component of the action plan, the government also recently put in place a program to prevent and minimize the impact of major natural hazards. The approximately $75 million program (Government of Quebec, 2006b), administered in collaboration with municipalities and regional stakeholders, will address problem situations related to coastal erosion, flooding and landslides. This initiative will guide all future planning in regards to infrastructure and buildings.

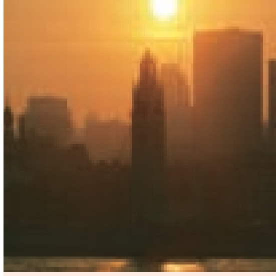
A number of sectors of society have already begun work on adaptation. At the municipal and provincial level, the priority issue is the reduction of GHG emissions, because no new or existing adaptation measures will be effective if action is not taken now to stabilize the future climate. Cities and towns, for example, are capturing the gas emitted by sanitary landfills, taking preventative measures to reduce emissions through changes in zoning and incorporating weather emergencies into emergency plans. Businesses are buying hybrid vehicles, working to lower trucks' maximum speed to save gasoline and reduce GHGs, replacing trucks by maritime transport, and moving towards geothermal heating systems. There is a long list of such initiatives, including the future carbon exchange in Montreal and the sustainable development and climate change response plan to be released in the near future by Quebec's health network.

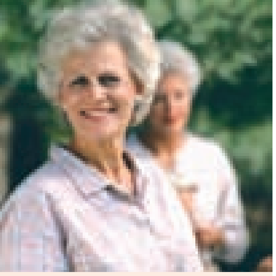
Still, programs remain to be defined, systematized, solidly budgeted and implemented. These programs must also be directed in particular to the people and communities who need or will need them and to those who do not or will not have the means of funding required infrastructures, services or other adaptations. Great differences, based on income and state of health, must be taken into account as well, as shown in this chapter with regard to access to air conditioning and pools during heat waves and adequate

heat during cold snaps. Differences in behaviours that vary according to age, gender, habits, ethnic origin and/or social environments must also be taken into account, particularly for effective awareness campaigns and warnings. With these considerations, an integrated public health program on adaptations to climate change can be realized. Many other factors that are brought forward in this chapter also warrant consideration. Most adaptations to climate change are interventions that have already been implemented (or could be implemented) by existing departments, agencies and local or regional municipalities. Nevertheless, these interventions exist for reasons other than the effects of climate change, and must be adjusted, better targeted and strengthened to address these effects.

Climate change presents a challenge of societal equity, between generations and regions, between the disabled and the able-bodied, and between the rich and the poor. It also presents the challenge of global equity. The World Health Organization recently reported that climate change already results in the death of more than 150,000 people each year, primarily in developing countries that cannot afford the infrastructure needed to address its effects or reduce GHGs, which are predominantly generated by the developed and wealthier countries, including Canada (Basu, 2005).

While investments in adaptation are on the rise, a single ingredient still seems to be lacking in order to maximize the opportunities present in all sectors of society: a clear and unequivocal message from senior levels of government regarding the need to think "adaptation" to the effects of climate change and a legal obligation for institutions to consider this in their daily decisions for the next two or three generations. The public in Quebec continues to deem this issue a very important one (Léger Marketing, 2006), as it has for several years.





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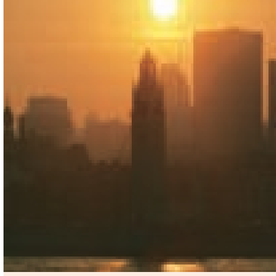

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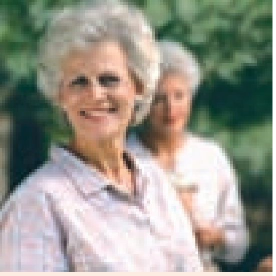

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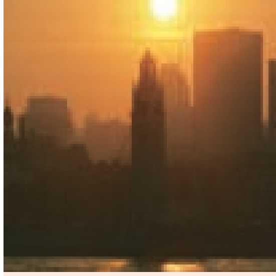

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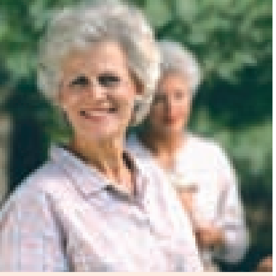

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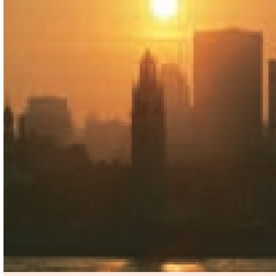

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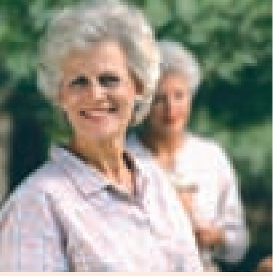

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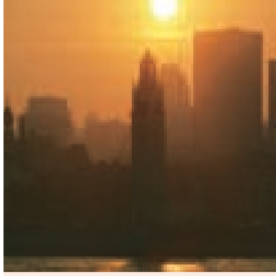

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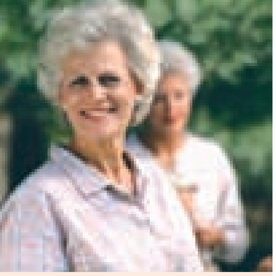

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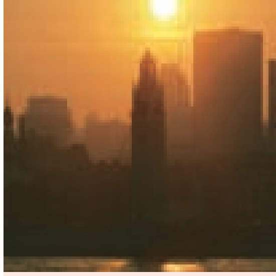

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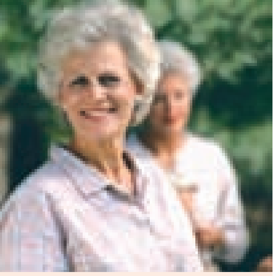

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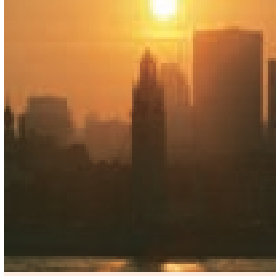

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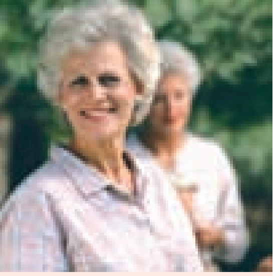

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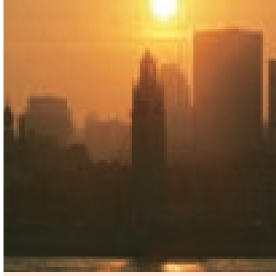

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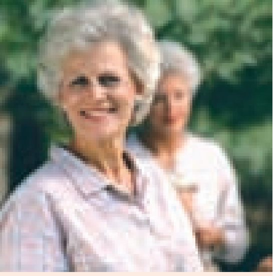

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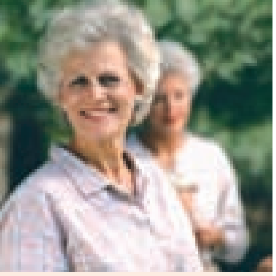

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Chapter 7

Health Impacts of Climate Change in Canada's North

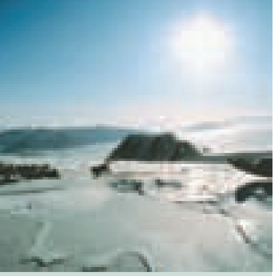
Photo Credits: Peter Langer

Christopher Furgal

Contributors:
Mark Buell
Laurie Chan
Victoria Edge
Daniel Martin
Nicholas Ogden

Chapter 7

CONTENTS



Chapter 7

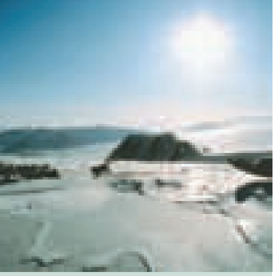
7.1 INTRODUCTION

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

Photo Credits: Peter Langer

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

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



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

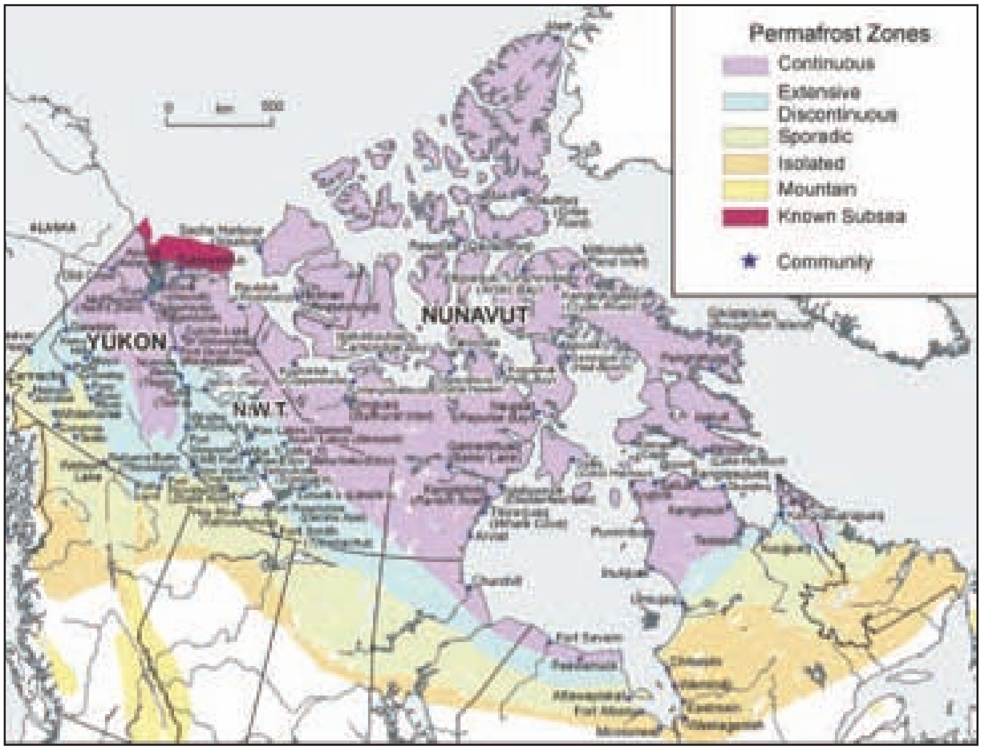
The increased pressures that polar regions are experiencing imply that they are approaching critical thresholds (such as thawing of permafrost and vegetation change), yet the exact timing and nature of these thresholds are not well known. Crossing these thresholds will likely trigger a cascade of effects,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

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

7.1.1 Climate Change and the Canadian North

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

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



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

Source: Furgal and Prowse, 2008.

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

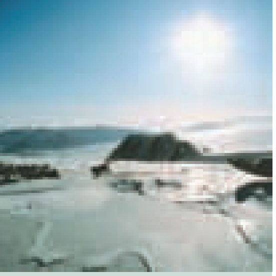
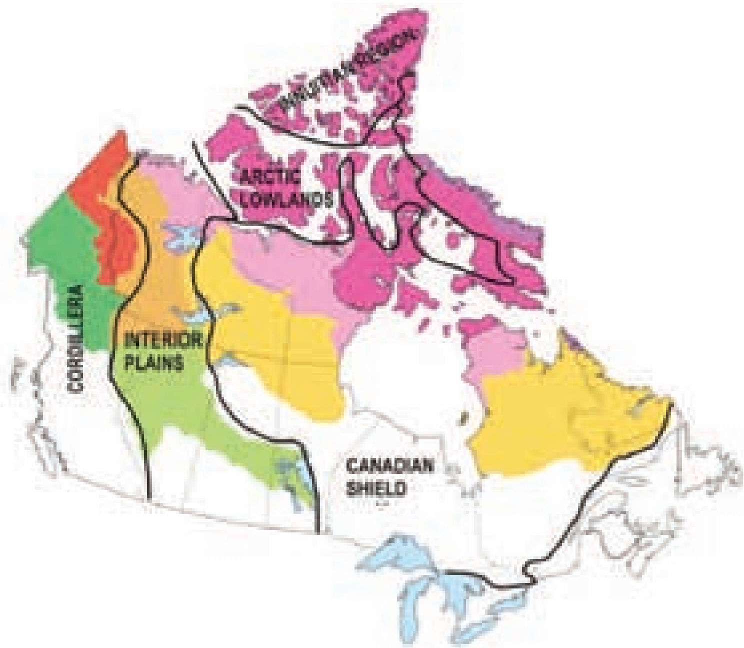


Figure 7.2 Physiographic and eco-regions of the Canadian North and their geographic and biological characteristics



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

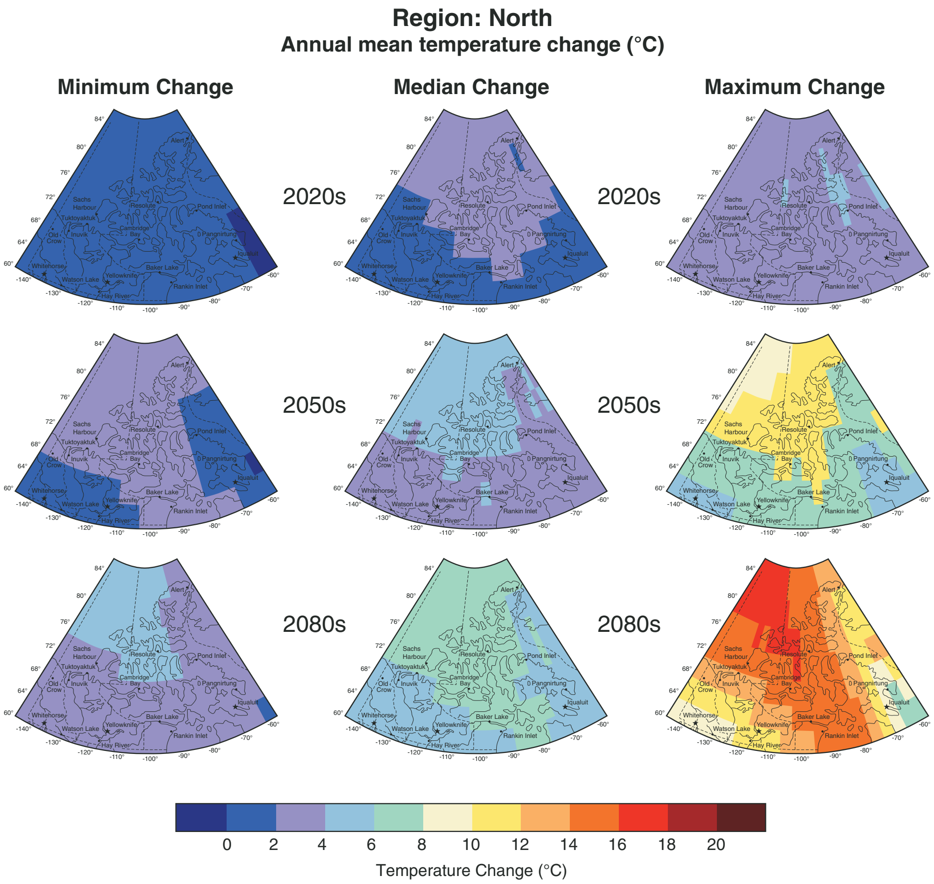
Source: Adapted from Fulton, 1989; Furgal et al., 2003.

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

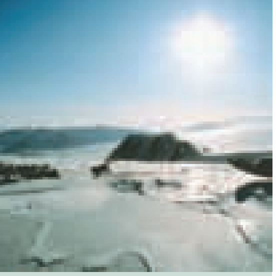
Climate simulations consistently indicate a "polar amplification" phenomenon, which is greater warming in the northern high latitudes compared with warming over the entire globe (Christensen et al., 2007). For the Arctic regions, climate models predict an increase in temperature of 2–4°C by the middle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

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

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



Source: Furgal and Prowse, 2008.



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

7.1.2 Focus of the Chapter

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

Photo Credits: Eric Loring

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

7.1.3 Methods

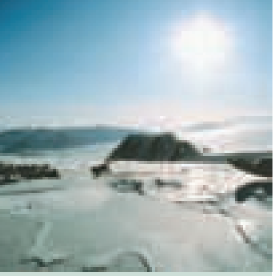
Climate change takes place amid a number of interacting social, economic and environmental variables across local, regional, national and international scales. It is therefore important to consider the vulnerability of "systems" which connect humans to their environment, and support ways of life, livelihoods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

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

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

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

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



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

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

7.2.1 Demographics

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

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

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

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

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

Source: Statistics Canada, 2006b.

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

Table 7.2 Selected health indicators for Canadian northern regions

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

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

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

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

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

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

Source unless otherwise indicated: Statistics Canada, 2003.

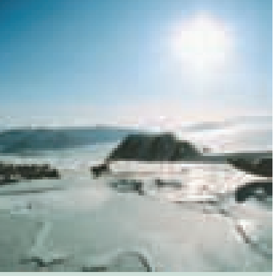


Table 7.3 Selected crude mortality rates by cause (per 100,000 deaths) for Canadian northern regions

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

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

* Source: INSPQ, 2006.

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

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

Source unless otherwise indicated: Statistics Canada, 2006a.

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

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

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

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

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

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

7.2.2 Population Density

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

Table 7.5 Population characteristics of Canadian northern regions

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

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

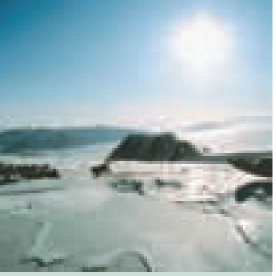
† The official Statistics Canada definition of "urban" is used where "urban areas" are those continuously built-up areas having a population concentration of 1,000 or more and a population density of 400 or more per km^2 based on the previous census; rural areas have concentrations or densities below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

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

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

7.2.3 Aboriginal Populations

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



Chapter 7

7.2.4 Health Status

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

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

Photo Credits: Peter Langer

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

Table 7.6 Selected social and economic indicators for Canadian northern regions

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

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

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

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

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

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

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

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

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

7.2.5 Socio-Economic Status

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

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

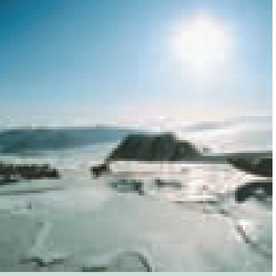
2 While the terms "country food" and "traditional food" are used differently by different aboriginal groups within Canada, they have been used interchangeably for the purposes of this chapter.

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

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

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

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

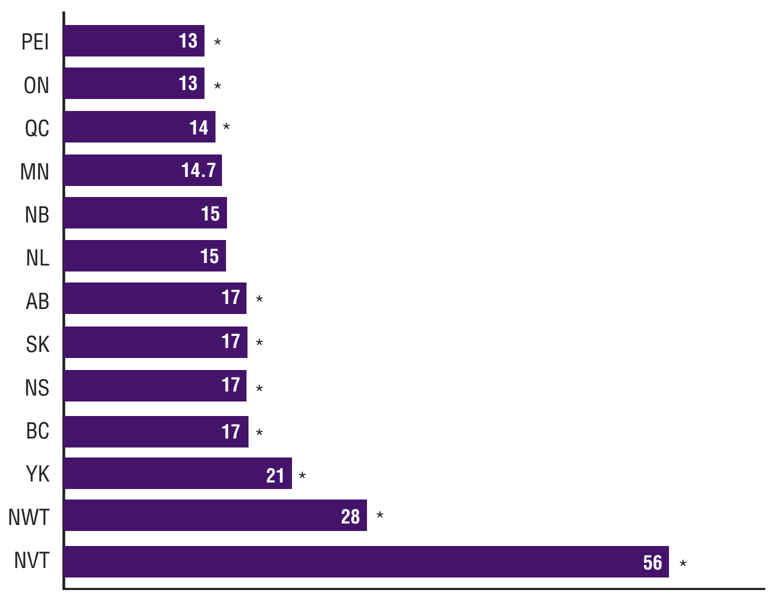


2001a; GNWT, 2005; CYFN, 2006). The housing issues are not uniform across the territories; problems (at least one of overcrowding, quality or affordability) are more often found among units in small communities (30%), compared with Yellowknife (9%) in the NWT (GNWT, 2005). Structural factors, social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

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

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

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



Data source: 2000/01 Canadian Community Health Survey

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

Source: Statistics Canada, 2005.

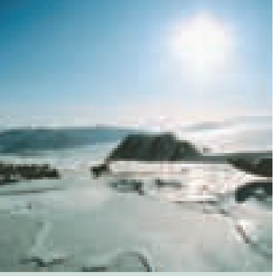
Table 7.7 Cost ($) of Northern Food Basket for selected northern and southern locations

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

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

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

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



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

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

7.3.1 Direct Impacts of Climate Change and Variability

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

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

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

Source: Adapted from Furgal et al., 2002.

7.3.1.1 Extreme precipitation events and natural hazards

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

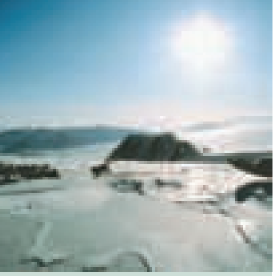
rain, freezing, heavy winds and snowfall on a crust of ice that allowed the destabilization of the snow mass were included among conditions reported as associated with this avalanche. Based on the analysis, a recurrence of the 1999 event every 50 years was estimated (Lied, 2000). Communities in Nunatsiavut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

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

7.3.1.2 Unpredictability of weather conditions

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

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



7.3.1.3 Temperature-related injuries

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

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

7.3.2 Indirect Impacts of Climate Change and Variability

Indirect health impacts of climate change are primarily related to:

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

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

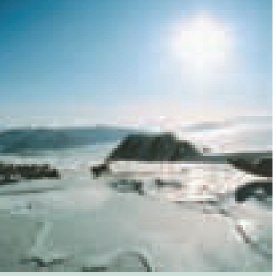
Identified Climate-Related Change	Potential Indirect Health Impacts
Increased (magnitude and frequency) temperature extremes	Increase in infectious disease incidence and transmission, psychosocial disruption
Decrease in ice distribution, stability and duration of coverage	Increased frequency and severity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

Source: Adapted from Furgal et al., 2002.

7.3.2.1 Climate warming and ice safety

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

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



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

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

7.3.2.2 Increased exposure to UV radiation

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

7.3.2.3 New and emerging diseases

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

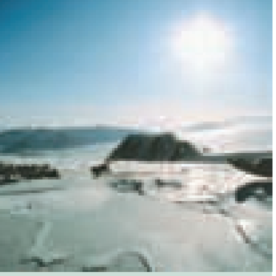
Many zoonotic diseases currently occur in Arctic host species, such as tularemia in rabbits, muskrats and beavers; rabies in foxes (Dietrich, 1981); brucellosis in ungulates, foxes and bears; echinococcosis in rodents or canine species (Chin, 2000); trichinosis in walruses and polar bears; and cryptosporidiosis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

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

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

Photo Credits: Peter Langer

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



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

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

7.3.2.4 Food security

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

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

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

Country/Traditional foods

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

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

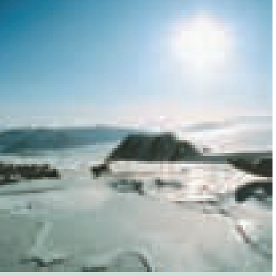
Table 7.10 Five country food items most often consumed (yearly average of days per week)

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

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

Source: Adapted from Kuhnlein et al., 2002.

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



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

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

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

Market foods

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

Photo Credits: Peter Langer

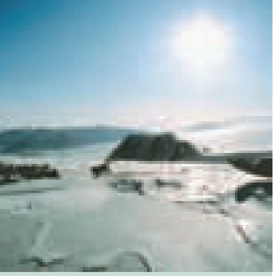
recommended levels of market items such as fruit and vegetables is considerably lower among northern residents than the national average, and is lowest among residents of Nunavut (Statistics Canada, 2005). In the NWT, males and older individuals were less likely to "eat well," as defined by *Canada's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

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

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

7.3.2.5 Water security

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



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

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

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

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

Source: Martin et al., 2005a.

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

7.3.2.6 Permafrost, coastal erosion and community infrastructure

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

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

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

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

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

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

(Pijamini, NTI Elders' Conference, 2001)

Photo Credits: Eric Loring

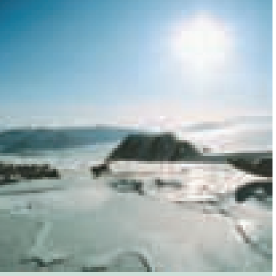
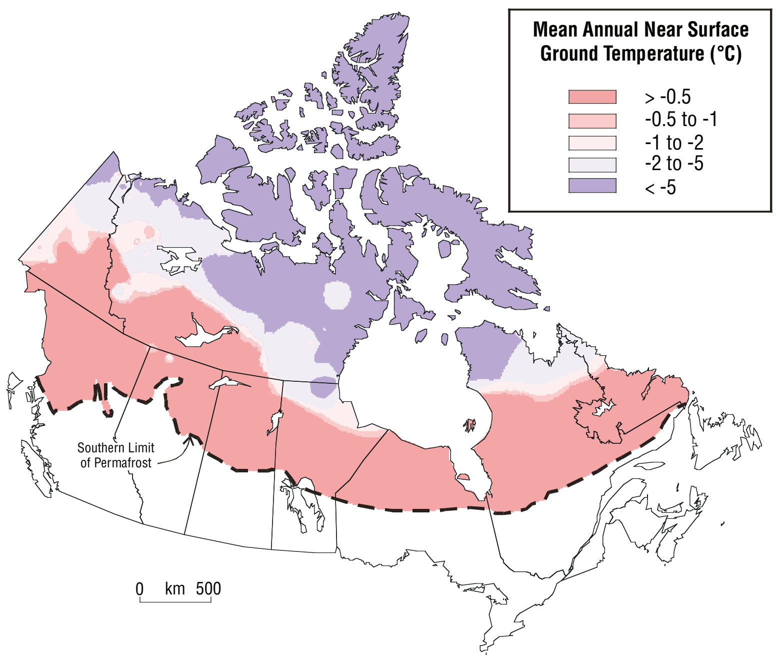


Figure 7.5 Spatial variation in mean annual near-surface ground temperature for the Canadian permafrost zone



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

Source: Smith and Burgess, 2004 unless otherwise indicated.

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

> *"People watch for erosion and have to move their cabins back from the river."*
>
> (Aklavik resident, Community of Aklavik et al., 2005)
>
> *"Long spits and points around the community are gone and it is predicted that the Hamlet office we are in now will be an island in 40 years."*
>
> (Tuktoyaktuk resident, Community of Tuktoyaktuk et al., 2005)

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

Chapter 7

7.3.2.7 Mental, social and cultural well-being

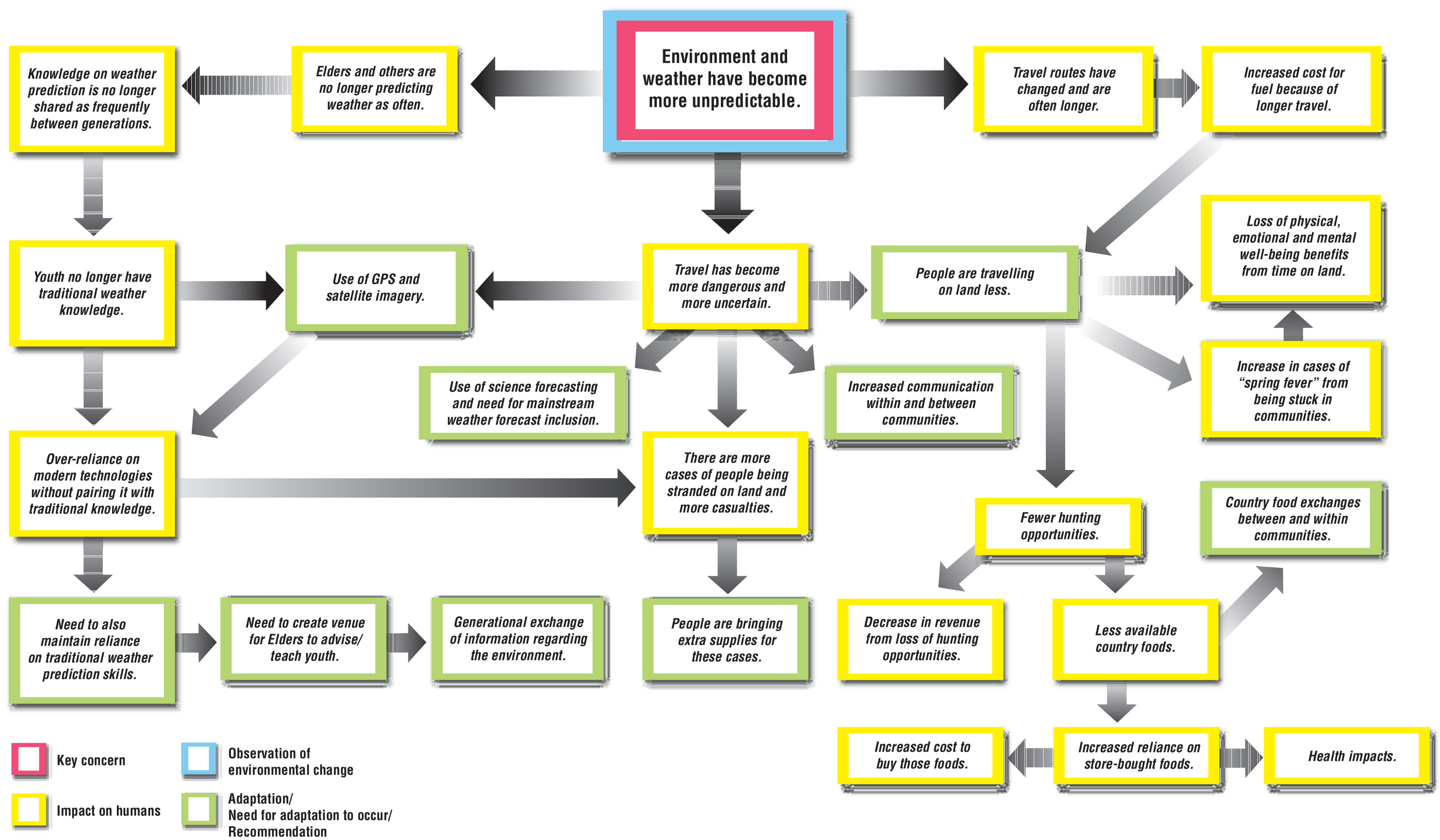
Many of the impacts described earlier in the text, on their own, or in concert with one another, represent forces of change to many northern residents for whom the connection with the local environment is a strong component of their mental health, culture and identity. Berner et al. (2005) and Curtis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

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

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

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

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



Source: Adapted from Nickels et al., 2006.

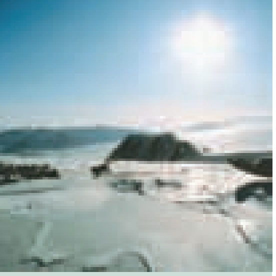
Chapin et al. (2005) stressed the importance of considering the synergies and trade-offs among the many forces at play within the context of climate, culture, development and health and well-being in polar regions when looking at the impacts of any factor or determinant. The increased growth of the wage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

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

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

Photo Credits: Peter Langer

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



Chapter 7

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

7.4.1 Adaptations

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

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

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

Photo Credits: Peter Langer

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

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

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

Source: Adapted from Nickels et al., 2002.

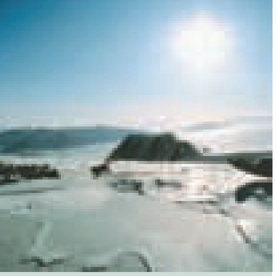


Table 7.13 Summary of current responses taken by individuals and communities in the North, as reported in the literature, assisting in their adaptation to climate change and variability

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

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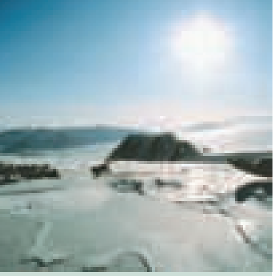
7.4.1.1 Precipitation extremes and natural hazards

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

7.4.1.2 Unpredictability of weather conditions

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

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



7.4.1.3 Temperature extremes

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

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

7.4.1.4 Warming temperatures and changing ice conditions

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

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

7.4.1.5 Increased exposure to UV radiation

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

Photo Credits: Peter Langer

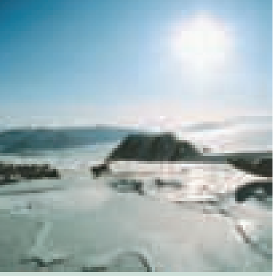
7.4.1.6 New and emerging diseases

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

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

7.4.1.7 Threats to food security

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



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

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

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

7.4.1.8 Changes in drinking water quality and accessibility

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

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

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

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7.4.1.9 Impacts on community and public health infrastructure

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

Photo Credits: Eric Loring

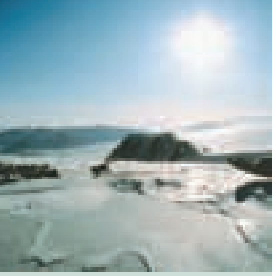
In some regions, communities are observing impacts of coastal erosion associated with increased storm surges and decreased sea ice cover, such as in the western Canadian Arctic. Adaptation to protect shorelines is taking place in the form of technological responses. In Tuktoyaktuk, NWT, the shoreline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

7.4.2 Adaptive Capacity

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

7.4.2.1 Economic and material resources

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



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

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

7.4.2.2 Technology

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

7.4.2.3 Information and skills

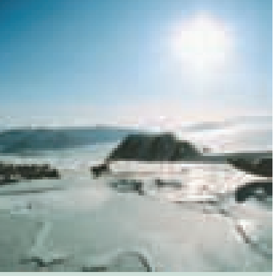
Access to information and skills influences both individual and collective capacities to cope with and respond to the health impacts of climate change and variability. A review of basic education statistics in the North reveals fewer years of formal education on average in regions with a higher proportion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

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

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

7.4.2.4 Institutional arrangements

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



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

7.4.2.5 Community and public health infrastructure

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

7.4.2.6 Disparities in health status

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

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

7.4.2.7 Socio-ecological resilience

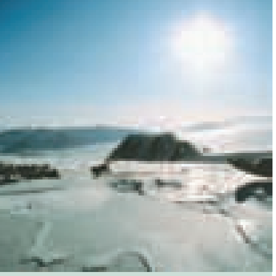
There is a growing body of literature on the historical adaptive abilities of Aboriginal groups in the circumpolar North and the applicability of these strategies today for addressing impacts from climate change. The adaptive capacity among Aboriginal groups that lived in the North in the past was associated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

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

7.4.2.8 Disparities in adaptive capacity

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

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



7.5 KEY VULNERABILITIES

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

7.5.1 Precipitation and Natural Hazards

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

7.5.2 Unpredictable Weather, Ice Conditions and Travel Hazards

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

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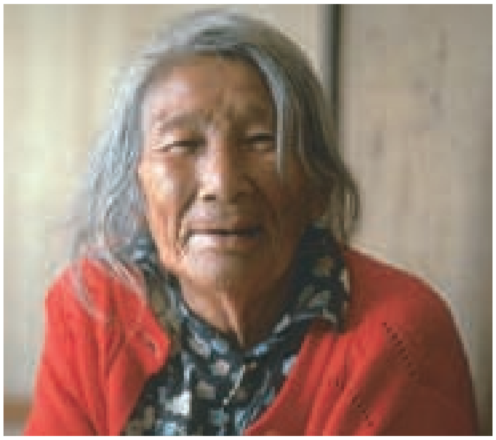
7.5.3 Temperature-Related Injuries

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

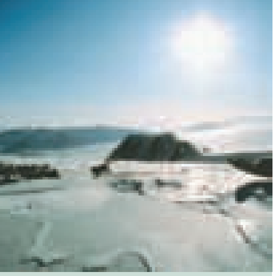


7.5.4 New and Emerging Diseases

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

7.5.5 Traditional Livelihoods, Food and Water Security

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



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

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

7.5.6 Permafrost, Coastal Erosion and Community Infrastructure

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

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

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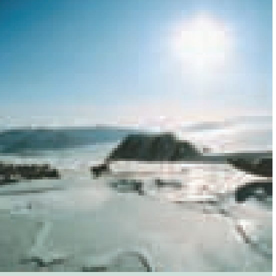
7.6 KNOWLEDGE GAPS AND CONCLUSIONS

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

7.6.1 Knowledge Gaps and Research Recommendations

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

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



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

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

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

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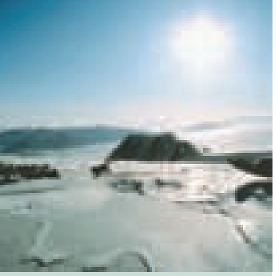
7.6.2 Conclusions

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

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

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

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



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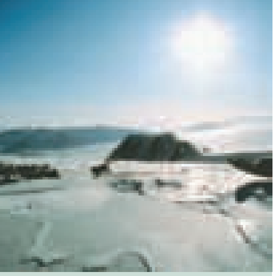

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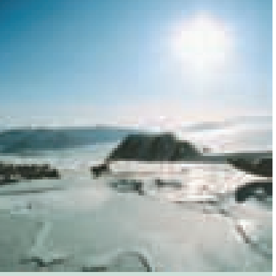

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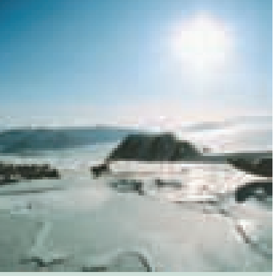

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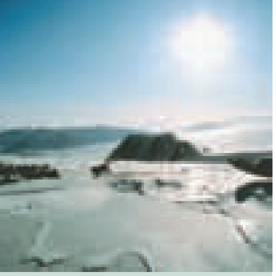

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Chapter 8

Vulnerabilities, Adaptation and Adaptive Capacity in Canada

Peter Berry

Contributors:
Quentin Chiotti
Kaila-Lea Clarke
Gylda Fry
Christopher Furgal
Dieter Riedel
Jacinthe Séguin

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8.1 INTRODUCTION

Global climate change is one of many large-scale environmental changes that reflect the increasing impacts of human activities on the environment. Other large-scale changes include stratospheric ozone depletion, biodiversity loss, worldwide land degradation, freshwater depletion and the global dissemination of persistent organic pollutants. Combined, they have important consequences for the sustainability of ecological systems, food production, economic activities and human population health (McMichael et al., 2003).[1]

According to the Intergovernmental Panel on Climate Change (IPCC), "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level" (IPCC, 2007b, p. 5). The rate of climatic change and its impacts will likely create new stresses on individual and community health and well-being, and increase vulnerability to already existing environmental and social pressures. The health effects of climate change are diverse and of varying importance but according to the IPCC "... are projected to progressively increase in all countries and regions" (IPCC, 2007a, p. 393). There is substantial evidence worldwide on the association between specific climate conditions and mortality, illnesses and discomfort (McMichael et al., 2003; Riedel, 2004; IPCC, 2007a). Previous chapters in this Assessment documented the health risks many Canadians and communities face across the country and how these may evolve as the climate changes. These include illnesses and deaths related to poor air quality, heat waves, water- and food-borne contamination, changing patterns of diseases spread by animals, ticks, and insects, and extreme weather events. Key segments of our population such as seniors and children, are often more vulnerable because of specific physiological sensitivities and reduced ability to cope by themselves with climate-related risks.

The extent to which climate change will disrupt society, affect the economy and reduce Canadians' quality of life and health will largely depend on the strength of existing systems to protect people from hazards, the willingness to adapt to short- and long-term changes and existing capacity to increase our efforts to adapt. Canadians identify climate change as an important threat to health; 81% of people surveyed in 2007 were concerned about climate change risks to health (Canadian Medical Association (CMA), 2007). This awareness is important for successfully implementing adaptation measures at the individual and institutional level.

Climate change may bring some benefits to the health and well-being of Canadians through reduced cold snaps (Gosselin, 2004; Riedel, 2004; Stern, 2006); however, Chapter 6, Health Impacts of Climate Change in Quebec, suggests that such benefits might be limited given that

1 The World Economic Forum ranked climate change to be the highest global environmental risk on the basis of severity of economic losses and number of possible deaths (World Economic Forum, 2007).

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people in that province are generally already well adapted to cold conditions. Potentially longer growing seasons for agriculture might also benefit Canadians economically, although this will depend on many factors, including future levels of heat stress, water availability and pest problems (Lemmen et al., 2008; IPCC, 2007a).

Adaptation[2] is not a new concept; many actions are being taken in Canada to reduce the health risks associated with weather extremes and longer-term climate variability. Health authorities within all levels of government, voluntary organizations and private organizations are responsible for a range of functions and services that may be affected by climate change. However, the existing systems vary in their effectiveness, and may not be fully protecting the populations most at risk. Severe weather-related hazards may be so overwhelming that current risk management efforts to protect human health and well-being may not be adequate or effective. And if newly developed policies and plans do not take into account the hazards associated with future climate change and the increased risks to human health and well-being, people will not be adequately protected.

Photo Credits: British Columbia Ministry of Foresta and Range

Kelowna, British Columbia, 2003

The public health community advocates for preventative interventions to manage risks related to climate variability and change (Kovats et al., 2003). However, preventing the onset of disease before it occurs requires an adequate knowledge of potential impacts and existing vulnerabilities, as well as sufficient capacity to act so that the necessary interventions can be developed. The capacity of individuals, governments and communities in Canada to adapt to the health risks associated with current climate variability and future climate change has rarely been subjected to rigorous analysis. Sparse information exists about individual adaptations and the effectiveness of protective measures used by Canadians and their communities; consequently, our understanding of vulnerabilities is incomplete.

This chapter examines the capacity of governments and communities to respond to climate change through an assessment of measures and systems that are in place to manage current climate-related health risks. It reviews results from new research, findings from other chapters of this Assessment and literature to draw conclusions about the sensitivity and exposure of Canadians to climate-related risks, and ultimately to provide insights about vulnerability. To support future adaptation efforts, it identifies current roles and responsibilities for managing climate-related health risks and provides an adaptation framework that offers guidance for developing needed measures to protect Canadians. It concludes by suggesting areas where adaptation efforts should focus and potential options for consideration by public health and emergency management officials.

2 "Adapting" means changing individual behaviours, and government policies and programs to help avoid the negative impacts of climate change, and to position Canadians to exploit its opportunities (Health Canada, 2005a). See section 8.10 for a more detailed discussion.

8.2 VULNERABILITY

There are many different definitions of vulnerability that arise from the use of this term in the natural hazards, risk management, poverty, public health and development literatures (Downing and Patwardhan, 2005). In the climate change impacts and adaptation field, vulnerability refers to "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007a, p. 21). The vulnerability of a population or region to the impacts of climate change is a function of (IPCC, 2001; Smit and Wandel, 2006):

1. Exposure to climate hazards
2. Sensitivity to those impacts
3. Adaptive capacity

For any given social and economic system, exposure is the probability of the occurrence of an ecosystem impact or effect (e.g. extreme weather event, emerging disease, smog episode) whose influence extends over a particular area (Adger, 2003). For human health, exposure refers to "the amount of a factor to which a group or individual was exposed; sometimes contrasted with dose, the amount that enters or interacts with the organism" (McMichael et al., 2003, p. 291).

Sensitivity is the "degree to which a system is affected, either adversely or beneficially, by climate-related stimuli" (Adger et al., 2003, p. 28). Sensitivity of individuals and populations can be influenced by a range of important determinants of health, such as socio-economic status, biology and genetic endowment, availability of health services, gender and personal health practices. Sensitivity to the impacts of current climate change and variability is also directly related to the effectiveness of current adaptations or measures to reduce the exposure to the impacts or mitigate the health risks.

Definition of adaptive capacity

Adaptive capacity is 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."

Source: IPCC, 2007a, p. 21.

Adaptive capacity provides an indication of the ability of a system to manage change successfully. Levels of adaptive capacity among individuals, communities and governments are often linked (Smit and Wandel, 2006). Individuals are better able to safeguard their own health when they reside in communities that possess high adaptive capacity, and communities benefit from comprehensive plans and responses put in place by regional and national governments. This chapter focuses on adaptive capacity as a key component of vulnerability.

It should be noted that "vulnerability" is used somewhat differently by emergency management practitioners and researchers. It is defined by this community in terms of "...conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. It is a measure of how well prepared and equipped a community is to minimize the impact of or cope with hazards" (Public Safety and Emergency Preparedness Canada (PSEPC), n.d. p.12). The level of vulnerability is not directly associated with the potential hazard; it is associated with other factors such as a person's age, education, income, disability, or a community's level of disaster preparedness.

Significant differences in vulnerability to the impacts of climate change exist among countries, particularly between developed and developing ones (McMichael et al., 2003). Developed countries have a significantly higher capacity to prepare for and respond to weather extremes and health emergencies. For example, between 1994 and 2003, 40,981 people in high human development countries were killed by hydro-meteorological disasters whereas 293,345 people in low human development countries were killed (International Federation of Red Cross and Red Crescent Societies, 2004).[3] It should be noted that an estimated 33,000 of the deaths in high human development countries are accounted for by a single event, the extreme heat wave in Europe in 2003. The importance of strong public health systems is also demonstrated by the striking contrast in disease incidence among some neighbouring countries. From 1980 to 1999, there were 64 reported cases of dengue fever in Texas but 62,514 cases over this same time period in three bordering states in Mexico (U.S. Department of State, 2002).

Differences in vulnerability also occur within countries because of disparities in resources. For example, some remote communities in Canada's North currently face greater adaptation challenges to climate change than most of their southern counterparts. Rapidly melting permafrost, which is used as the base for ice roads, makes it difficult to resupply communities such as Tuktoyaktuk with food, medicines and other necessities (Munro, 2006). This is occurring at the same time that changes in the health of animals (e.g. caribou) and in their migration routes and distribution are occurring. Consequently, several communities no longer have safe or consistent access to country foods for long periods (Nickels et al., 2006). As well, gaps in some public health services and systems exist in many northern communities.

3 The classification of countries as high, medium or low human development in *World Disasters Report 2004: Focus on Community Resilience* is based on the United Nations Development Programme's 2003 Human Development Index (International Federation of Red Cross and Red Crescent Societies, 2004).

8.3 VULNERABILITY ASSESSMENT APPROACH

The main objective of vulnerability assessments is to identify feasible adaptation options to reduce the effects of climate change (Smit and Wandel, 2006). An initial assessment of the vulnerability of a population or community can be made without detailed information about how the climate will change in the future. Such analysis draws from information about the sensitivity and exposure of populations to past climate variability, as well as from information about the current capacity of systems to adapt to changing conditions (Lemmen and Warren, 2004).

Current levels of vulnerability are related to the adaptive measures in place and the effectiveness of a range of traditional public health activities (IPCC, 2007a). Existing measures for reducing climate-related health risks and emergencies may increase or decrease future vulnerability; this information can be used to identify gaps that need to be addressed.

Several conceptual and analytical frameworks for assessing vulnerability and adaptive capacity related to climate change have been developed and published (Smit and Pilifisova, 2001; Downing and Patwardhan, 2005; Ford and Smit, 2005). As discussed in Chapter 2, Assessment Methods, the best guidance document for the assessment of adaptation to climate change, in relation to human health, has been identified by Füssel and Klein (2004) as *Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change* (Kovats et al., 2003). However, this document provides limited guidance for the exploration and assessment of adaptive capacity as a key factor in determining vulnerability. For this reason, the approach followed here also draws upon the *Framework for Assessing Vulnerability for Climate Adaptation* developed by Downing and Patwardhan (2005). This framework emphasizes key activities, including assessing the exposure to climate hazards, particularly for vulnerable populations; assessing sensitivity; gauging adaptive capacity; examining future vulnerability; and linking the vulnerability assessment outputs with adaptation policy options.

The approach used here to examine adaptive capacity in Canada therefore included the following steps:

- Identify determinants of adaptive capacity to guide analysis.
- Identify concerns about current adaptation efforts and the capacity of public health and emergency management systems to reduce health risks, based on analysis of current adaptations and measures.
- Integrate information about sensitivity and exposure of Canadians to hazards associated with climate variability and change to provide preliminary insights about the vulnerability of Canadians.
- Identify roles and responsibilities, and current adaptations in Canada for safeguarding human health and well-being.
- Identify possible adaptation measures that can be employed to reduce risks to health and to build adaptive capacity and reduce vulnerabilities.

8.4 METHODS

Adaptation options and the capacity of Canadian communities and governments to address climate-related health risks were investigated according to the key health issues that are the focus of this Assessment.[4] It should be noted that the analysis of adaptive capacity is not specific to any province or region of Canada, unless so indicated. For this reason, estimates are not provided on relative levels of existing capacity among specific regions or communities. The adaptive capacity of communities in northern Canada and in the province of Quebec is discussed in Chapter 7, Health Impacts of Climate Change in Canada's North and Chapter 6, Health Impacts of Climate Change in Quebec, respectively.[5] The analysis in this chapter also focuses on the capacity of existing institutions and organizations to adapt rather than the capacity of individual Canadians.

Various sources of data were used for analysis in this chapter. Information on roles and responsibilities for adaptation was obtained through the Internet: websites of government and non-governmental sources, and in particular, the websites of the agencies responsible for the provision of health care, public health, safe drinking water and emergency management services. The inventory is not comprehensive but, for the purpose of examining adaptive capacity in Canada, it provides a synopsis of the key differences in responsibilities among jurisdictions and organizations.

A literature review and expert informant interviews with public health and emergency management officials were used to identify existing concerns about the capacity of governments and communities to address the health risks related to climate variability, including those expected to increase because of climate change. The literature review used information available from international agencies (e.g. World Health Organization (WHO)) and from national, regional and local authorities (e.g. Health Canada). Some information on the capacity of public health systems to plan for and respond to health emergencies is available because of recent events such as the severe acute respiratory syndrome (SARS) outbreak in Toronto, and the illnesses and deaths in Walkerton, Ontario, caused by the contamination of the water supply by *E. coli 0157:H7* and *Campylobacter jejuni.* Analysis of these events provided information about levels of capacity for protecting Canadians during public health emergencies. It also provided information about measures to strengthen public health systems—measures that could be applied to better protect the health of Canadians under conditions of climate change. This information, along with recent actions to improve capacity, such as creation of the Public Health Agency of Canada in 2004 and the position of Chief Public Health Officer for Canada, is drawn upon for the analysis in this chapter.

There is a paucity of peer-reviewed studies on climate change and health adaptation and adaptive capacity in Canada. Therefore, this chapter partially draws upon the grey literature, including unpublished workshop reports and working papers, memoranda, public health protection procedures, and guidelines from health and emergency management agencies and other relevant sources. Inferences made from the international literature, which has grown substantially over the last few years, are presented with care and in a manner that respects the specific circumstances of Canadian governments and communities.

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4 Adaptation measures and adaptive capacity related to risks from increased exposure to ultraviolet radiation due to stratospheric ozone depletion are not examined in this chapter.

5 See Chapter 2, Assessment Methods, for the rationale for including these regions in this Assessment.

Health and emergency management experts and practitioners from academia, government and non-governmental organizations at municipal, provincial and federal levels were consulted through health emergency management simulation exercises (i.e. a heat wave in Montreal and two storm surge simulations in Atlantic Canada) and through surveys. Workshops organized by Health Canada were also held to obtain information on current adaptations and key determinants of adaptive capacity. These consultations highlighted the need to examine the capacity of a wide range of decision makers and organizations (such as governmental authorities and practitioners), and the need to examine both current and future vulnerabilities (Health Canada, 2003a).

Calls being made during storm surge table-top simulation exercise in Port-aux-Basques, Newfoundland and Labrador, 2005

Relatively few climate change and health assessments have been conducted, and few of these include systematic and comprehensive assessments of adaptation measures and adaptive capacity. Approaches and methods for assessing adaptive capacity and vulnerability are still being refined. Conceptual frameworks and methods do not exist to allow for precise quantification of existing adaptive capacity, including that of decision makers within non-governmental and governmental organizations. As well, uncertainty about future changes in risks and the diversity of health impacts across areas and regions are key challenges faced by such assessments (Füssel and Klein, 2004; Lemmen and Warren, 2004). For these reasons, this chapter constructs a snapshot of current adaptations in Canada, and identifies key concerns and trends regarding current adaptive capacity from a variety of available sources. Health and emergency management officials routinely make decisions under conditions of uncertainty about how to best address threats to public health by using risk-based approaches that are designed for this purpose (Health Canada, 2000). It is therefore expected that the findings of this chapter will be useful in deliberations about how to most effectively address future health risks associated with climate change.

8.5 ASSESSING ADAPTIVE CAPACITY

Adaptive capacity is generally assessed by examining the current state of the system or region, and its ability to deal with current stresses, such as climate variability. A measure of the effectiveness of current policies and programs is key to understanding existing capacity (Spanger-Siegfried and Dougherty, 2003). Well documented research on the key determinants of capacity and the existing levels of capacity to adapt to health risks related to climate change in Canada is lacking. In support of this Assessment, Health Canada consulted with experts and practitioners to identify determinants important for managing health risks and contributing to adaptive capacity (Health Canada, 2003a). The determinants

that were highlighted correspond to those identified by WHO, which are described in the following text. These included access to material resources (i.e. economic wealth), technology, information and skills, institutional arrangements, public health infrastructure, equity and the existing burden of disease (Grambsch and Menne, 2003).

Economic resources

Wealthy nations and wealthy communities within nations are better able to adapt because they have the economic resources to invest and to offset the costs of adaptation. For example, over the past decade, disasters in developed countries resulted in an average of 44 deaths per event whereas disasters in less developed countries killed an average of 300 people per event (International Federation of Red Cross and Red Crescent Societies, 2004).

Technology

Access to technology in key sectors and settings (e.g. agriculture, water resources, health care, urban design) is an important determinant of adaptive capacity. Many adaptive strategies, such as the development of vaccines to combat infectious diseases, involve new technological developments. Storm prediction and warning services by Doppler radar and communications systems (e.g. television, weather radio) are technologies that are important for warning citizens and preparing communities for threats from extreme weather events.

Information and skills

Information sharing and awareness-raising activities are important for communicating health risks associated with climate variability and change, and the adaptive actions that can be taken to protect people (WHO, 2005). Countries with more “human capital” or knowledge also have greater adaptive capacity. As well, health systems are labour-intensive, and require skilled and experienced staff such as those trained in the operation, quality control and maintenance of public health infrastructure.

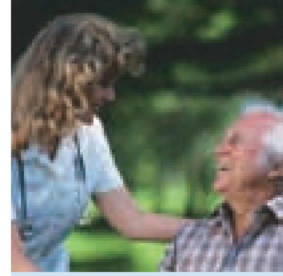
Institutions

Strong and effective institutional arrangements are an important determinant of adaptive capacity (Grambsch and Menne, 2003). Ineffective or maladaptive public health policies and programs, and a lack of collaboration among relevant agencies and organizations can create an inability to meet health needs. Collaboration between public and private sectors, such as the Ouranos Consortium in Quebec or the Prairie Adaptation Research Collaborative in Alberta, can greatly facilitate research on climate change impacts and the development of the needed adaptations to address health risks.

Infrastructure

Roads, railways, bridges, water systems, power plants, telecommunications facilities, mass transit, ports and airports are all fundamental for maintaining the quality of life and health of people living in a community. Infrastructure specifically designed to increase resiliency and reduce risks

Photo Credits: Alberta Government



from climate extremes (e.g. flood control structures, air conditioning, building insulation), and general public health infrastructure (e.g. sanitation facilities, wastewater treatment systems, laboratory buildings) reduce vulnerability by enhancing adaptive capacity (Grambsch and Menne, 2003).

Equity

Adaptive capacity is likely to be greater when access to resources within a community, nation or the world is equitably distributed. Under-resourced populations and jurisdictions may lack the means to plan for climate change impacts.[6]

Existing burden of disease

Population health and well-being is an important determinant of adaptive capacity (McMichael et al., 2003; IPCC, 2007a) because it contributes to the ability to regain a state of physical, mental and social well-being in the face of significant challenges and changes (e.g. loss of a job for an individual or loss of an industry for a community). Some populations and regions in Canada have significantly lower health status than others (e.g. the North),[7] and therefore may be more vulnerable to the health impacts of climate change and have less capacity to adapt.

There is no guiding framework or consensus on the criteria required for evaluating the determinants of adaptive capacity and on the indicators that should be used (Lemmen et al., 2008). Few of the proposed methods and procedures for assessing the adaptive capacity of communities clearly identify specific measures for gauging the ability to address expected impacts. Using indicators to measure adaptive capacity also presents significant challenges; this is because indicators say little about the processes that make systems and populations vulnerable and that determine whether these systems and populations can adapt to new climate hazards (Brooks and Adger, 2004). Therefore, this chapter does not develop and use indicators to measure capacity. Rather, it highlights key concerns about the capacity of governments and communities in Canada to address climate-related health risks that have been raised in recent reports, audits, research projects, expert interviews, workshops and surveys during this study. These concerns are based on important findings about limitations in the effectiveness of current adaptations that are aimed at reducing climate-related health risks.

6 Internationally, the obligation of developed countries to provide assistance to less developed ones for their adaptation efforts is included in the United Nations Framework Convention on Climate Change.

7 Detailed discussion of the adaptive capacity of Canada's northern communities can be found in Chapter 7, Health Impacts of Climate Change in Canada's North.

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8.6 ADAPTIVE CAPACITY IN CANADA

Our ability to adapt to the health impacts of climate change depends on the rate and magnitude of the changes in the future (U.S. Department of State, 2002). More rapid climate change or warming, creating greater ecosystem changes and extreme weather events, could result in health risks that would increasingly challenge our existing capacity to respond. The cumulative impacts of a number of extreme events or health emergencies test the capacity of a community or region to respond as well as their resiliency (i.e. ability to return to normal) (Smit and Wandel, 2006). For example, many Prairie communities, particularly those located in river valleys and along floodplains, are subject to cumulative natural and other hazards. These include floods, droughts, heat waves, hailstorms, blizzards, tornadoes, chemical spills during transport and power outages (Haque, 2002). If these were to occur in quick succession, health and social service providers could be overwhelmed.

Extreme weather events are incurring increasing economic costs to individuals, communities, businesses and governments in Canada. Between 1900 and 1970 the estimated direct damage costs of weather-related disasters in Canada was $4.8 billion while from 1990 to 2000 the estimated cost was $13.7 billion (PSEPC, 2005). Significant numbers of Canadians have concerns about the ability of their governments to deal with health emergencies. A survey in 2006 revealed that 39% of Canadians and 34% of doctors feel that the health care system is not well prepared for a public health emergency, such as flooding or a disease outbreak (e.g. SARS). Only 6% of Canadians think the health system is "very prepared" (POLLARA, 2006).

Current adaptations may not be sufficient to reduce exposures and address sensitivities to protect Canadians from the more severe hazards (e.g. more intense extreme weather events) and longer-term changes expected with climate change (Lemmen et al., 2008; Health Canada, 2005a; Roberts et al., 2006). As indicated in other chapters of this Assessment, risks to human health and well-being will likely increase, particularly as the rate of change quickens. Projections of increased risks related to climate change suggest that greater adaptation efforts and enhanced capacity in Canada will be required to prepare and plan for the expected climate-related hazards (Chiotti et al., 2002). A key step in enhancing our efforts to protect Canadians from climate-related health risks is to gain understanding of the effectiveness of current adaptations and of areas where gaps exist in adaptive capacity (Kovats et al., 2003). Such information can inform future adaptations and help decision makers track progress toward strengthening institutions, programs, policies and human resources to protect health from the effects of climate change.

Canadians have engaged in a wide range of activities aimed at enhancing health and well-being in the face of weather patterns and extremes associated with the Canadian climate (Riedel, 2004). The scope of public health interventions that could be classified as adaptations to climate-related health risks is enormous. A formal cataloguing of current activities in Canada was therefore not conducted in this chapter. The following sections discuss key adaptations in Canada and concerns that have been identified regarding such measures and our current capacity to cope with climate-related hazards and associated health risks. The discussion is organized according to health issue and includes information on recent actions by federal, provincial and municipal governments to enhance capacity.

8.6.1 Adapting to Health Risks from Natural Hazards

IPCC indicates that the rate of climate warming will increase over the coming decades and that it is very likely that heat waves and heavy precipitation events will become more frequent (IPCC, 2007b). It is also likely that tropical cyclones (i.e. hurricanes) will become more intense (IPCC, 2007b).

Past adaptation efforts in Canada have limited to a large extent the impacts of natural disasters and other health emergencies. Disaster trends in developed countries, such as Canada, show a decline in fatalities during this century due to factors such as improved warning systems, building codes and safety knowledge (Kovacs, 2006). Among the current measures to reduce risks to human health and personal property from extreme weather, the Meteorological Service at Environment Canada issues over 30 types of weather alerts, including weather watches, warnings and special statements.[8] Approximately 14,000 severe weather warnings are issued to communities across Canada annually (Environment Canada, 2003). As well, some communities have built specially designed infrastructures (e.g. Winnipeg floodway) to reduce risks from natural hazards.

Photo Credits: Environment Canada – Canadian Hurricane Centre

Hurricane Juan damage at Prospect, Nova Scotia, 2003

However, weather-related disasters such as prolonged droughts, floods, hurricanes and wildfires continue to pose health risks for Canadians. For example, Hurricane Juan,[9] which was a Category 2 hurricane that hit Nova Scotia on September 29, 2003, resulted in extensive damage to central Nova Scotia and Prince Edward Island, and was responsible for eight deaths. More than 300,000 people were without power for up to a week and a half and it was the most costly hurricane in Canadian history (McBean, 2006).[10] In addition, such events may have significant long-term psycho-social health impacts on individuals, such as depression, post-traumatic stress disorder and anxiety. Currently, there is little information about the prevalence of such impacts associated with past weather-related emergencies and disasters in Canada (Hutton, 2005), but it is generally acknowledged that they are significant (Gutman, 2007).

Critics have suggested that current capacity to respond to health emergencies in Canada is limited (Street et al., 2005). Recent reports and audits conducted in response to a number of emergencies in Canada (e.g. floods in Manitoba; 1998 Ice Storm in eastern Canada; wildfires in British Columbia; water safety issues in Walkerton, Ontario, and Battleford, Saskatchewan; SARS; Creutzfelt-Jacob disease; 2003 Ontario blackout) have examined the ability of the health sector and others to respond to unpredictable events and other emergencies.

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8 See Annex 1 for a list of the different types of weather alerts issued by Environment Canada.

9 See Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, for detailed information on the impacts of Hurricane Juan and the community response.

10 Other recent weather events in Canada have seriously impacted individuals and disrupted communities. For example, the 1998 Ice Storm caused massive power outages that affected 4.7 million people in eastern Ontario, Quebec and New Brunswick. Over 600,000 had to be evacuated, and 28 deaths and 945 injuries occurred. Total damages were estimated at $5.4 billion (Public Safety and Emergency Preparedness Canada (PSEPC), 2007a). In July 2000, a tornado hit Pine Lake, Alberta, causing 27 deaths and 600 injuries, and displaced close to 1,700 people (PSC, 2007c). See Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, for a more detailed discussion of such impacts.

8.6.1.1 Emergency management

There is broad recognition in Canada that there is a need to enhance our efforts to plan, prepare for and mitigate the more frequent and intense extreme weather events that are projected to occur because of climate change (Health Canada, 2001; Lemmen and Warren, 2004; The Conference Board of Canada, 2007). A recent parliamentary review of emergency preparedness in Canada (Standing Senate Committee on National Security and Defence, 2004) identified a number of concerns that need to be addressed to ensure Canadians are adequately prepared to face future hazards and extremes. Recommendations in the report called for several measures such as:

- improved leadership and coordination by the federal government on emergency preparedness matters;
- improved funding assistance mechanisms that allow provinces and municipalities to undertake preparedness activities;
- improved communications and coordination among response agencies, communications with the public, access to critical supplies and training;
- improved information about emergency health stockpiles and access to them for municipalities;
- more capacity within the Canadian Forces to provide support to municipalities in large emergencies; and
- improved linkages on emergency preparedness matters among municipal, provincial and federal governments.

> "....accumulating risks associated with factors such as increased urbanization, critical infrastructure dependencies and interdependencies, terrorism, climate variability and change, animal and human health diseases and the heightened movement of people and goods around the world have increased the potential for various types of catastrophes. Such events could transcend geographic boundaries to challenge FPT emergency management, including response" (PSEPC, n.d., p. 3).

The need to make Canadian communities safer in the face of increasing emergencies and disasters has also been recognized as a federal/provincial/territorial priority in both the public health and health emergency management sectors in Canada (Federal/Provincial/Territorial (F/P/T) Network for Emergency Preparedness and Response, 2004).

National voluntary organizations with their networks, experience and expertise are well positioned to play an effective role in assisting communities to prepare for and respond to the challenges of climate change. However, with certain exceptions, neither government agencies nor voluntary organizations have the mature systems, plans or networks required to facilitate voluntary sector involvement in activities related to adaptation to the health risks associated with climate change. A recent survey conducted by the Canadian Red Cross (2005) indicated that 64% of voluntary sector organizations with a specific mandate in emergency preparedness did not have a service continuity plan. The same survey revealed that over 75% of responding organizations without a clear mandate in emergency preparedness, but willing to mobilize their volunteer resources on this issue, did not have an up-to-date service continuity plan. Consequently, the voluntary sector may have difficulty responding to increasing pressures to aid in preparing for and responding to greater risks to Canadians from climate-related hazards.

Chapter 8

Case study: Storm surge simulations in Atlantic Canada

In 2005, two 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, federal government and non-profit organizations actively participated in the simulation exercises. 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 improve future collaboration among stakeholders.

Several recommendations, which correspond closely to determinants of capacity analyzed in this chapter, were proposed to enhance the effectiveness of response capabilities and protect the communities. These include (Health Canada, 2006b):

Institutions

- Ensure an annual update of emergency response plans (e.g. names, telephones, procedures).
- Coordinate actions within the municipal emergency plan with the needs of surrounding communities.
- Establish a coordination process between municipal emergency planners and other organizations involved (e.g. hospitals, community services, coast guard, provincial ministries).
- Update emergency response plans for local health services.
- Ensure coordination between local health centres and community organizations.
- Include procedures to follow in case of a sudden, severe outbreak of a disease (epidemic) and/or terrorism act in the municipal emergency plans.
- Be prepared for the possibility of multiple and simultaneous public health crises (e.g. storm surges, epidemics).

Information sharing and skills

- Clearly define the criteria for declaring a state of emergency.
- Better define roles and responsibilities of people involved in response.
- Identify communication alternatives (e.g. satellite phone, very high frequency (VHF) radio).
- Offer training in emergency response for key municipal personnel.
- Include community organizations (e.g. Red Cross, churches, Salvation Army, seniors' clubs) in all emergency planning steps.
- Create a regional list of public health services available in an emergency situation.
- Make available an emergency medical telephone line to the public.

Infrastructure

- Identify needed human resources and equipment (e.g. generators) locally and regionally available.
- Ensure the municipality has the necessary tools to facilitate the exchange of information during an emergency (e.g. meeting room, maps, boards for logistic information such as weather conditions, record of decisions, contact information).
- Do not depend extensively on regional resources (human and equipment) because they are often solicited by all affected communities in an emergency.

8.6.1.2 Research, education and training

The increasingly "risky" environment faced by municipalities, including the potential impacts of climate change, has demanded more risk assessments, a more rigorous approach to the development of emergency management plans, and more training for emergency services personnel and public health officials. Several municipalities and senior-level government departments have undertaken risk analyses to support their emergency planning, but these have been done mostly on an informal and ad hoc basis. Except in a few cases, these analyses have not factored in climate change within a systematic risk management approach. A divergence between emergency management and adaptation to climate change exists across all levels of government in Canada (Noble et al., 2005).

As well, Canada significantly lags behind countries such as Australia and the United States in establishing emergency management education programs, and consequently suffers from a lack of educated professionals and researchers working in this field (Bruce et al., 2005). There is a shortage of qualified Canadian educators to develop and deliver courses, to supervise post-graduate students and to conduct research (Bellisario et al., 2007). As well, few provinces require certification for emergency management professionals in Canada (Bruce et al., 2005). However, significant strides have recently been made in the development of Canadian course materials and programs for practitioners, and the development of certificate programs across the country is well underway (Bellisario et al., 2007).

A key informant survey of public health officials in cities of various sizes across Canada revealed a broad awareness of climate change and related health issues. All respondents indicated that weather and climate do have a significant impact on health and most (76%) stated that climate change will increase risks to health in their respective jurisdictions (Health Canada, 2006d).[11] However, more than half of those in the survey indicated that climate change had not been identified as a priority public health issue in their geographic jurisdictions; the reasons most often cited were a lack of funding and, particularly, a lack of information or understanding of whether, and why, climate change is a pertinent issue for the public health sector (Health Canada, 2006d). Respondents who did report that climate change was considered an important public health issue in their jurisdiction also indicated that it was not considered a high priority (Health Canada, 2006d). The need for better understanding of health risks associated with climate change is reflected in a resolution passed by the Canadian Public Health Association in 2001 calling for more research into the health impacts of climate change (Canadian Public Health Association (CPHA), 2001b).

8.6.1.3 Critical infrastructure

> "Extreme events such as floods, droughts and heat waves are likely to increase under global warming and will challenge our ability to manage health risks and test the resilience of our infrastructures in many areas, including health service delivery."
> (Kovats and Haines, 2005, p. 501)

Physical infrastructure plays a vital role in sustaining the health of Canadians. Weather extremes and events can debilitate key infrastructure, posing significant direct (e.g. drownings) and indirect (e.g. mental stress from economic dislocation) health impacts.[12] Public capital investment to maintain and improve infrastructure in Canada has not kept pace with the growing economy and the demands of its population (Harchaoui et al., 2003). Much of Canada's infrastructure is nearing the end of its designated life (Haque, 2002). Almost 30% of the nation's public infrastructure is over 80 years old; only 40% is under 40 years old. Canadians have used on

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11 Results of a survey of public health and municipal decision makers, as discussed in Chapter 6, Health Impacts of Climate Change in Quebec, also revealed a high level of awareness about potential risks to health from climate change. As well, a resolution from the Ontario Public Health Association in 2004 recommended the development of programs to address the health impacts of extreme weather events related to climate change (Ontario Public Health Association, 2004).

12 For example, Hurricane Juan (2003) and the Ice Storm (1998).

average almost 80% of the useful life of all public infrastructure in the country (Zuker, 2004).[13] While a recent report shows that the average age of some categories of infrastructure has decreased, overall significant challenges remain and require sustained action (Statistics Canada, 2008). Definitions of public infrastructure vary, as do estimates regarding the extent of infrastructure needs. There is however, consensus on the need to take action.

The current state of infrastructure in Canada could make Canadians more vulnerable to future weather extremes and hazards because the capacity to withstand extreme environmental events is reduced (Haque, 2002; Office of the Auditor General of Canada (OAG), 2006). Damage to buildings from weather can be caused by storm winds, rain penetration, poor durability of construction materials, flood damage, coastal erosion and foundation movement (City of Hamilton, 2006). Extreme weather events associated with climate change are of concern because even small increases in weather and climate extremes have the potential to bring large increases in damage to existing infrastructure. As Auld and MacIver stated, "the damage from extreme weather events tends to increase dramatically above critical thresholds—the high impact storms associated with damages may not be much more severe than the type of storm intensity that occurs regularly each year" (Infrastructure Canada, 2006, p.1). In response, disaster mitigation, including climate change adaptation, has been incorporated into recent federal infrastructure programming as an eligible funding category and climate change impacts are examined during the project assessment process.

A 1995 survey by the Federation of Canadian Municipalities (FCM) found that 59% of the water distribution networks in Canada and 43% of water supply systems were in unsatisfactory condition. Breaks and leaks plague the water mains in older cities, and over 50% of water distribution networks were noted to perform unsatisfactorily. It was also found that 68% of sanitary and combined sewers, 58% of sewage treatment systems and 53% of storm sewers did not operate at an acceptable level and needed some type of repair. The FCM survey also noted that wastewater treatment and conveyance crises have emerged in communities of all sizes throughout Canada (Infrastructure Canada, 2003).

Greater action is needed to implement adaptation measures to make Canada's infrastructure more resilient and to facilitate adaptation in other jurisdictions (OAG, 2006). More resilient infrastructure means lower health risks through reduced risk of structural failure that can accompany extreme events. Recent impacts of climatic events on key infrastructures in Canadian communities demonstrate the need to develop new infrastructure designs that can resist larger and potentially more damaging events expected under climate change (City of Hamilton, 2006). As current infrastructures are upgraded and replaced, engineers need new and updated design values, revised codes and standards, and new methodologies to incorporate climate change considerations into engineering procedures (McBean and Henstra, 2003; Infrastructure Canada, 2006).

Infrastructure failure in Toronto

A severe thunderstorm event with rainfall intensity greater than that experienced during Hurricane Hazel (1954) hit northern Toronto on August 19, 2005. It resulted in the failure of a culvert under Finch Avenue. The entire roadbed of Finch Avenue West at Black Creek was washed away affecting all of the city and utility infrastructure within the road allowance. The storm cost $500 million in insured losses due to flooding, collapsed roadways and lost "buried" infrastructure. It also resulted in significant traffic disruptions caused by the loss of the roadbed.

Source: Infrastructure Canada, 2006.

13 The expected life cycle of bridges, housing, commercial buildings, seaports and rail infrastructure is 50 to 100 years; that of dams, water supply infrastructure, sewers and airports is 50 years; and that of roads and waste management facilities is 20 to 30 years (Infrastructure Canada, 2006).

Infrastructure that provides health services to a population needs to have the capacity to cope with extreme weather events (IPCC, 2007a). Hospitals are key to Canada's health services infrastructure. An emergency that cripples a community or region's hospital services can become a disaster claiming hundreds of lives and affecting thousands of people. Improved emergency management measures for Canada's hospitals are needed. Important shortcomings have been identified in emergency communications strategies in general hospitals (Ferrier, 2002). Many hospitals require better plans for acquiring surge capacity during times of emergencies (e.g. sharing of staff). Limited coordination between hospital plans and those of the community, and limited testing of emergency protocols (e.g. evacuation procedures) have been identified as factors that increase the vulnerability of these institutions, and of patients, to the impacts of emergencies and disasters. Finally, there is a lack of training of those responsible for emergency planning in hospitals. Only 37% of officials had completed an emergency preparedness course in a recent survey of Canadian hospitals (Ferrier, 2002).

8.6.1.4 Rural–urban divide

An examination of emergency preparedness in Canada revealed differences in capacities between cities and smaller communities, or rural areas of Canada, to plan and prepare for emergencies and disasters. Small communities and rural areas[14] are less prepared than large cities (Haque, 2002). Communities not served by adequate transportation or communications infrastructures may be isolated for extended periods of time, compounding hardship. A key informant survey of community emergency preparedness officials found that smaller centres face significant problems with emergency planning and preparedness functions (e.g. training and testing plans) because of insufficient financial and human resources. Most of these smaller centres did not employ specialized emergency planners. In comparison, almost all medium and large communities had designated a full-time official to be responsible for emergency preparedness and coordination (Egener, 2005). Another study (Haque, 2002) comparing rural and urban communities identified the following key challenges facing rural communities in their efforts to improve preparedness:

- reliance on volunteers for emergency personnel;
- lack of economic resources to cope with hazards;
- an underestimation of the frequency of events and hazards because of a lack of knowledge and risk assessments; and
- inadequately trained or organized emergency personnel.

14 Rural communities are defined here as communities with fewer than 1,000 inhabitants. This is consistent with the definition used by Statistics Canada.

Costs to Canadian municipalities are of particular concern. Costs for security and emergency management are increasing rapidly because of many factors, such as increasing urbanization and concentration of populations and increasing climate variability (Egener, 2005). In addition, assistance with emergency preparedness training has been reduced by federal and, in some cases, provincial governments, leaving municipalities to develop and deliver this training or else contract it out. Ultimately, less than half of the smaller centres indicated that their response in the event of an emergency would be effective (Egener, 2005).

Important differences between rural and urban communities concerning their ability to implement a range of programs exist. A survey of public health officials in cities of different sizes across Canada revealed that although most communities consider climate-related information in planning and program development (e.g. air and water quality advisories), the largest cities have the broadest range of initiatives to protect health from weather- and climate-related hazards (e.g. monitoring of West Nile virus and/or Lyme disease, air quality levels, ultraviolet (UV) levels, water quality). They also engage in more research on the health impacts of air pollution, issue extreme weather warnings, and have action or outreach plans on climate change (CPHA, 2006).

8.6.1.5 Risk perception and attitudes of individual Canadians

A primary responsibility for preparing for extreme weather events and reducing the risks they pose to protect health and well-being falls to individual Canadians and households (Murphy et al., 2005; Remedios, 2005). Public Safety and Emergency Preparedness Canada (2007b) advises that Canadians should know what disaster risks they face, develop an emergency plan, have a kit on hand that provides provisions to last three days and know what to do in the event of an emergency. Actions to prepare for emergencies could also include doing home repairs to reduce hazards, purchasing disaster insurance and obtaining first aid training (Murphy et al., 2005).

Many residents in the North, a region in Canada currently experiencing particularly severe impacts from climate change,[15] are changing their behaviours to adapt to weather-related risks. For example, communities in Nain, Labrador, are taking many actions to minimize the dangers associated with unpredictable weather. This includes performing ice-track tests before travelling, notifying people about the safety of travel routes and forming search-and-rescue teams (Furgal, 2002).

> "Experience has shown us that household emergency preparedness is one of the most effective means of mitigating the personal effects of a disaster. By preparing emergency provisions, members of a household can turn what could be a life-threatening situation into a manageable problem" (Falkiner, n.d. p. 14).

However, most individuals are largely unprepared for emergencies (Murphy, 2004). Citizens generally plan only for the immediate future, overestimate their ability to cope when disaster strikes and rely heavily on emergency relief (Tierney et al., 2001). A survey of 576 households was conducted in Kingston, Ontario, in 2001 to determine levels of emergency preparedness for extended winter power outages, fires and medical emergencies. It indicated a generally low level of preparedness among respondents and highlighted a number of areas where improvement was necessary (Falkiner, n.d.). Many Canadians do not view themselves as being at risk from extreme weather. A national survey of Canadians in 2001 found that 60% of Canadians either somewhat disagreed (34%) or strongly disagreed (26%) with the statement that extreme weather in their area posed a risk to themselves, their family or their property (Ipsos-Reid Corporation, 2001).

15 See Chapter 7, Health Impacts of Climate Change in Canada's North, for more information.

8.6.1.6 Recent actions to improve adaptive capacity

In recent years, considerable progress has been achieved towards developing a more integrated and robust emergency preparedness and response capacity in the health sector (Health Canada, 2005a). Many provinces have taken actions to strengthen emergency planning in their respective jurisdictions. Several now require that municipalities conduct hazard assessments and have emergency preparedness plans (McBean and Henstra, 2003; Egener, 2005). For example, Ontario's *Emergency Management and Civil Protection Act* (2006) requires communities and the provincial government to establish emergency management programs, based on hazards and risks that the people of Ontario may face. The Act provides emergency powers to the premier and to the lieutenant governor-in-council to ensure that the provincial government has the necessary power to react quickly to an emergency (e.g. evacuations, closing public places, disposing of environmental or animal waste) (Government of Ontario, 2006). In October 2006, Emergency Management Ontario launched a one-year all-hazards warning system pilot that warns citizens of imminent threats to life and property from man-made and natural hazardous events such as floods, forest fires, unsafe drinking water or chemical spills. Public safety warnings are broadcast across two cable channels, The Weather Network and its French counterpart, MétéoMédia (Ontario Ministry of Community Safety and Correctional Services, 2006).

Following the 1998 Ice Storm that debilitated Quebec, eastern Ontario, New Brunswick and Nova Scotia for a number of weeks, the province of Quebec took important steps to strengthen emergency preparedness and response capacity; the province is now much better able to cope with future extreme events (Lemmen et al., 2008). For example, during the crisis it purchased 57,000 cots and blankets from the Red Cross; this has provided the province with the ability to open many more emergency shelters if confronted with other large-scale disasters (D. Shropshire, pers. comm., October 15, 2005). The province also created Ouranos, a consortium initiative of Hydro-Quebec, the Quebec Government and other partners, to build an understanding of regional climate change and its environmental, social and economic impacts. The Ouranos Consortium is developing the research tools necessary to provide decision makers with detailed climate change scenarios on a regional scale. In fall 2006, the Consortium adopted a research component on climate change impacts on human health.

Health measures under Quebec's climate change action plan

- Setting up an alert system for intense heat and for monitoring, in real time, related health problems in all regions of Quebec likely to be affected.
- Supporting health services building managers in analysis of the ventilation/air conditioning/dehumidification needs of care institutions, taking into account climate change.
- Improving systems for monitoring infectious diseases to allow for quickly detecting pathogens and diseases whose development is accelerated by climate change.
- Developing training, to be offered to workers in the public health, clinical services and civil protection sectors, on diseases and emerging health problems related to climate change and their treatment.
- Introducing a short- and long-term epidemiological monitoring system for physical and psychological health problems related to extreme climate events.
- Financial support for the creation of cool areas (e.g. tree planting, creation of parks, installation of municipal pools) in urban communities and cooling for strategic infrastructures (e.g. hospitals, homes for the elderly, schools) to mitigate the impact of summer heat waves on the population.

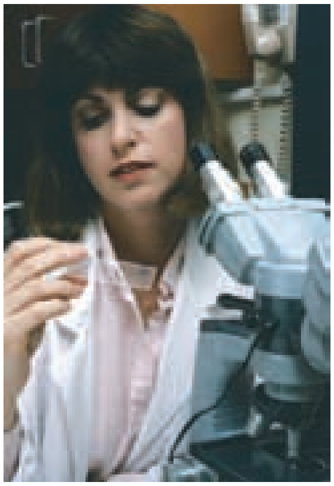
Source: Government of Quebec, 2006.

National Framework for Health Emergency Management

In 2001, the federal, provincial and territorial Ministers of Health acknowledged the need for a comprehensive, integrated and coordinated strategic plan for managing health emergencies in Canada (Health Canada, 2005a). In response, the National Framework for Health Emergency Management was developed to provide a consistent, inter-operational approach to health emergencies at a pan-Canadian level (F/P/T Network for Emergency Preparedness and Response, 2004). This framework aims to enhance the capacity of local, provincial and federal authorities to prepare for and respond to emergencies by fostering operational bridges based on shared principles, guidelines and operating procedures. Key principles of the National Framework include an all-hazards and consequences approach, resiliency and sustainability of programs and planning, and comprehensive management practices that balance mitigation, preparedness, response and recovery. This all-hazards approach examines the full range of threats and their implications for Canadians—in terms of their individual and public health impacts, as well as community and societal effects. Although controlling infectious diseases and other health emergencies continues to be a priority, this new approach begins to bridge the gap between climate change and health emergency management policy and decision making (Health Canada, 2005a).

8.6.2 Adapting to Health Risks from Water-, Food-, Vector- and Rodent-Borne Diseases

To prepare for the expected health impacts of climate change, WHO has advocated for a general strengthening of public health and health care services. In particular, "The maintenance of national public health infrastructure is a crucial element in determining levels of vulnerability and adaptive capacity" (McMichael et al., 2003, p. 14). Public health authorities play a critical role in monitoring and taking action to maintain health and well-being within the whole community. This is accomplished by the following three primary activities (Carty et al., 2004):



- health protection—reducing or preventing risks through a variety of activities (e.g. food and water safety, immunization, handling of toxins);
- health screening and surveillance—the early detection of disease to facilitate treatment; and
- health promotion—education and outreach activities on a variety of issues to reduce or prevent risks (e.g. smoking, injury prevention, nutrition, reproductive health).

Among other activities, local, provincial and federal health departments in Canada maintain registries of health data on certain diseases, infections, hospitalizations and injuries; WHO monitors similar data at a global level. These data, which are collected by recording events as they occur, contribute to passive surveillance and may be enhanced by active surveillance programs that obtain data on particular health problems (e.g. emerging infections) (Pinner et al., 2003). The national *Notifiable Diseases On-Line* and *Canada Communicable Disease Report* allow access to information on case reports and surveillance results of infectious diseases.

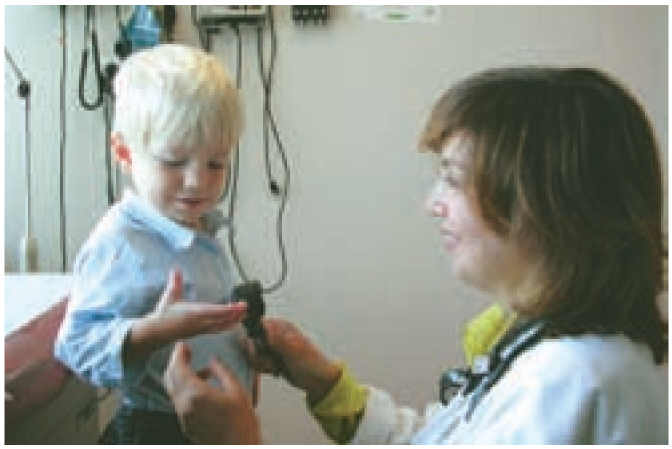
The effectiveness of policies and programs for responding to disease outbreaks and emergencies in Canada has recently been examined following outbreaks and other events that have taken place during the past decade. These outbreaks and events have tested the capacity of public health and emergency systems. Several of the key areas for improvement highlighted in these reports are discussed in sections 8.6.2.1 to 8.6.2.5.

8.6.2.1 Institutional coordination and planning

A common gap in dealing with health emergencies and infectious disease outbreaks at a pan-Canadian level was the absence of a common approach to provide consistent and inter-operational procedures. A national legislative and policy framework for a measured, harmonized and unified response to pan-Canadian health emergencies was highlighted as a critical need (Health Canada, 2003b; F/P/T Network for Emergency Preparedness and Response, 2004). More generally, population health strategies that address the health outcomes of the full range of determinants of health—encompassing social, environmental, cultural and economic factors—have been called for (Standing Senate Committee on Social Affairs, Science and Technology, 2003). This includes programs and services that recognize different health care needs of men and women, visible minorities, people with disabilities and new Canadians (Commission on the Future of Health Care in Canada, 2002).

8.6.2.2 Health system and public health resources

Past funding levels for health system and public health functions, including those dedicated to the prevention and control of infectious diseases, have been identified as insufficient to meet existing service needs (Commission on the Future of Health Care in Canada, 2002). Other studies highlighted the need to bolster public health infrastructure (CPHA, 2001a; Health Canada, 2003b) and ensure that emergency departments have the physical facilities and equipment to achieve minimal facility standards for emergency situations. Capacity is needed to ensure that hospitals that serve as regional centres can be equipped with the appropriate infrastructure to allow their participation in surveillance networks—including the receipt of necessary national and international alerts (Health Canada, 2003b). Greater resources are required to support provincial, territorial and regional capacity for infectious disease surveillance, outbreak management and related infection control activities (Health Canada, 2003b).



8.6.2.3 Information sharing and exchange

The ability of Canadian health officials to exchange and share data and information on disease outbreaks and emergencies in a timely and accurate manner across jurisdictions is critical to their ability to respond effectively and adapt to new situations (e.g. inter-provincial surveillance reporting). Several studies have reported a need to improve the ability of officials to share information (CPHA, 2001a, 2001b; Health Canada, 2003b; Standing Senate Committee on Social Affairs, Science and Technology, 2003). A report by Health Canada in 1999 found that some of the information about the health of Canadians is not organized to meet the needs of health professionals and policy makers (Health Canada, 1999). To address these concerns, more timely access to laboratory testing and results, using common technology platforms and typing procedures, has been recommended, as well as the development of management protocols for infectious disease outbreaks (Health Canada, 2003b; Standing Senate Committee on Social Affairs, Science and Technology, 2003).

8.6.2.4 Human resource planning and training

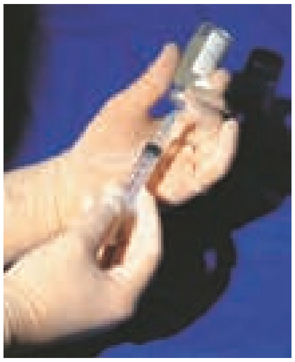
Several studies have recommended that greater attention needs to be paid to human resource planning and training to buttress the ability of communities to respond to infectious disease outbreaks and public health emergencies, particularly at a time when many health service facilities are overtaxed. Health care delivery services in Canada currently experience high demand. Although 87.7% of Canadians had a regular family physician in 2001 (Health Canada, 2002b) and, in 2003, 84.9% of Canadians were satisfied with the health services they received (Health Canada, 2004b), one in 10 Canadians reported unmet needs for health care in 2003 and 32% of those named waiting for care as a barrier (Canadian Institute for Health Information (CIHI), 2006b). As well, in 2004, 48% of Canadians reported waiting more than two hours to be treated in an emergency room (CIHI, 2005).

Improved human resource planning is needed to create a reserve or "surge" capacity to deal with public health emergencies (CPHA, 2001a, 2001b; Commission on the Future of Health Care in Canada, 2002; Health Canada, 2003b; Senate Standing Committee on Social Affairs, Science and Technology, 2003). A recent survey of health practitioners in Ottawa indicated that family physicians in that city perceive their offices as unprepared to address serious health crises (Hogg et al., 2006). Only 18% thought their offices were prepared to respond to a serious respiratory epidemic and 50% believed they were not prepared (Hogg et al., 2006).

Several studies recommended a comprehensive plan be developed for addressing issues related to supply, distribution, education and training, remuneration, skills, and patterns of practice for health professionals in this country (CPHA, 2001a, 2001b; Commission on the Future of Health Care in Canada 2002; Health Canada, 2003b; Standing Senate Committee on Social Affairs, Science and Technology, 2003). Improving surge capacity to protect health in times of emergency is particularly important given that Canadians are at increased risk to the health impacts from more frequent and intense extreme weather events.[16] Improving crisis communication activities has also been identified as a pressing need; further training of health professionals to facilitate the sharing of information with the public during health emergencies is required (Health Canada, 2003b).

8.6.2.5 Recent actions to improve adaptive capacity

In the wake of the SARS outbreak in 2003 and the many calls to bolster the public health system, a new Public Health Agency of Canada (PHAC) and the position of a Chief Public Health Officer for the country were created in 2004. Increased investments in public health functions created and strengthened a variety of programs: the International Centre for Infectious Diseases, which focuses on research, training, commercialization and innovation in addressing the threat and impacts of infectious diseases; a Skills Enhancement for Public Health program; a Pan-Canadian Framework for Public Health Human Resources Planning; and a Public Health Scholarship and Fellowship Grant Program. Increased investments have also targeted the development or application of leading-edge technologies, such as the Public Health Map Generator that PHAC makes available to public health professionals across Canada. This program enables them to quickly and easily visualize their local health data by using web-based map applications (PHAC, 2006). PHAC is also contributing to the building of an International Vaccine Centre at the University of Saskatchewan. This facility will be the first of its kind in the world, unique in its focus on vaccine development for both animal and human pathogens. It will be a level three high-containment testing facility that will develop vaccines to stop the spread of infections such as West Nile virus, Creutzfelt-Jacob disease and SARS (PHAC, 2007a).



16 See Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, for more information.

The capacity of health officials to undertake needed surveillance activities to detect and then effectively manage a host of risks to human health has been enhanced in Canada. Infectious diseases, including those that pose increased risks to Canadians and people worldwide due to climate change, require rapid and early detection. Early detection of outbreaks provides public health officials in Canada, other countries and international bodies, such as WHO, early warnings for preventative and remedial actions. PHAC operates the Global Public Health Intelligence Network, an Internet-based early warning system. The system gathers preliminary reports of public health significance from around the world 24 hours a day, seven days a week, and disseminates relevant information on disease outbreaks and other public health events to users in the public health community within and outside of Canada (PHAC, 2004). This system has been credited with recognizing the outbreak of SARS in China in 2002 and contributing to limiting the spread of the disease (Sommer, 2006). Additionally, the Canadian Integrated Public Health Surveillance program at PHAC provides an integrated suite of computer and database tools to Canadian public health professionals to support needed surveillance activities (PHAC, 2007b).

The contamination of drinking water with *E. coli 0157:H7* and *Campylobacter jejuni* in Walkerton in 2000—the most serious water-borne disease outbreak in Canadian history (seven deaths and 2,300 illnesses)—initiated a review and improvement of water supply regulation in Canada. After this event, many provinces revised their standards to align with the Canadian Drinking Water Quality Guidelines developed by Health Canada. To support provincial and territorial partners in efforts to protect the health of Canadians from health risks associated with contaminated drinking water supplies, Health Canada and PHAC are undertaking a number of actions. These include the development of a web-based system designed to report boil water advisories and notify stakeholders across Canada, the development of the technical document *From Source to Tap: Guidance on the Multi-barrier Approach to Safe Drinking Water,* and facilitating the sharing of information through the Federal/Provincial/Territorial Committee on Drinking Water.

Efforts are also being made under the First Nations Water Management Strategy to ensure that clean and safe drinking water is accessible in First Nations communities in Canada. In May 2003, the federal government announced $600 million in new funding under this strategy to improve the delivery of clean and safe water, as well as wastewater treatment services, to First Nations communities.

New water treatment facility for Walpole Island First Nation

In November 2005, the federal government committed $10 million to replace the current water treatment facility at Walpole Island First Nation. Walpole Island First Nation has an on-reserve population of 2,200 and it is located near Wallaceburg, Ontario. There are approximately 650 homes on-reserve at Walpole Island, most of which are serviced by the community's current water treatment facility. The existing facility, which operates at full capacity, will be replaced by a new water treatment plant in 2008. Through the First Nations Water Management Strategy, a total of $67.2 million has been provided since 2003 for 54 major plant upgrades or replacements. These projects which are currently under design, construction or have been completed, will improve water quality in 45 First Nations communities in Ontario.

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

8.6.3 Adapting to Health Risks from Air Pollution and Heat Waves

It is widely accepted that current global warming trends will continue and that excess mortality is associated with extreme temperatures and heat waves (IPCC, 2007a).[17] Increasing temperatures can also affect the chemical reactions involved in the creation of air pollution. Concern over the health risks associated with heat waves and increased smog levels has precipitated calls for the development of warning and protection systems in Canada (Cheng et al., 2005).

8.6.3.1 Air quality indices

Timely information about the risks to health from air pollution can play an important role in changing personal behaviours to minimize these risks. Smog advisories are the first line of defence in terms of protecting the health of Canadians from exposure to air pollution. Integral to these advisories is the Air Quality Index that provides information on a daily basis about local air pollution conditions. Currently, there is no standard air quality index used across Canada. All provinces except Saskatchewan (and no territories) and, in some cases, municipalities (e.g. Montreal) have developed their own indexes. They have done so with support from the federal government in the form of scientific, monitoring and technical assistance. There is also a lack of consistency in the way that air quality is calculated and reported, and in the use of health-based messages (Environics Research Group, 2005). As well, a recent survey of physicians in Canada found that almost none of those surveyed provide information to their patients about air quality and health as a regular part of their interactions with patients, although all believe that outdoor air quality has a negative impact on health and many feel the impact is significant. The physicians identified a lack of time, a lack of information and an insufficient understanding of the topic as barriers to addressing the health implications of poor air quality with patients (Environics Research Group, 2006).

Despite the relative success of the air quality indices, various groups have expressed concerns about fundamental flaws in the assumptions used in their calculations. These concerns are largely health-based, reflecting that there are no known thresholds for ozone and fine particulate matter, that the air standards upon which the index is based are outdated, and that the majority of health effects occur outside smog advisory periods (Chiotti, 2006). As well, the current Air Quality Index may be less effective at changing individual behaviour than desired. Individuals tend to disassociate air quality health risks from their own situation, either by underestimating their own exposure or assuming the risks apply primarily to other people they believe are most vulnerable (e.g. seniors). Most Canadians know that air quality indexes or advisories are provided in their area. But this information is having a limited impact in attracting attention and prompting actions to reduce personal exposure, even during poor air quality events (Health Canada, 2005a). Also problematic is that there is no central registry in Canada recording smog advisories on a national basis, although there are websites that provide provincial or regional air quality data in varying degrees of detail (Chiotti, 2006).

8.6.3.2 Smog response plans

Municipal smog response plans generally consist of a communications plan, a communications network and operational actions to reduce emissions of harmful air contaminants. The plans typically involve four central activities (Chiotti, 2006):

- educating the community about the health effects of air pollution;
- documenting, monitoring and reporting on local air quality;
- developing a management strategy to reduce local emissions contributing to air pollution; and
- preparing the community to respond appropriately to smog events.

17 The IPCC stated, "It is more likely than not that anthropogenic forcing through emissions of greenhouse gases has increased the risk of heat waves" (IPCC, 2007b, p.10) and that "it is *very likely* that hot extremes, heat waves and heavy precipitation events will continue to become more frequent." (IPCC, 2007b, p.15).

Many municipalities in south-central Canada have developed long-term clean air plans, and most of them have included a smog response plan component. However, there is a spatial disconnect in smog response plans vis-à-vis regions that use an air quality index, which could emerge as a serious health problem. Few, if any, municipalities outside of south-central Canada have smog response plans in place, although several communities across Canada experience air pollution episodes that pose risks to health. Many of these communities have developed air management strategies and/or are taking actions to reduce GHGs (Chiotti, 2006). While the current number and distribution of smog advisories suggests that this is not yet a serious problem, smog conditions could change significantly under climate change (Chiotti, 2006).[18]

8.6.3.3 Other actions

Although adaptive actions are important for reducing an individual's exposure to both air pollution and extreme temperatures, mitigation actions to reduce emissions of air pollutants are required to further lessen the health risks associated with such atmospheric conditions (Health Canada, 2005b). Measures to reduce the emissions of GHGs can have immediate health benefits by directly reducing the emission of chemical airborne pollutants. Mitigation actions to reduce both air pollutants and GHGs are in line with the preventative approach to climate change advocated by the public health community (CPHA, 2001c). The capacity of individuals, communities and governments to reduce air pollutants and GHG emissions is an important complement to adaptive actions, but is not investigated in this chapter.

8.6.3.4 Heat alert systems

Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, demonstrates that robust emergency management policies and programs, including early warning systems and emergency response plans, constitute key adaptation measures for lowering the risks to human health from extreme weather events and other natural disasters. Analysis of the health impacts of the 2003 heat wave in Europe underscores the importance of these, and other, risk management policies and the high costs of not being prepared (WHO, 2005).

Heat alert systems can be effective in reducing heat-related illnesses and deaths (Smoyer-Tomic and Rainham, 2001; Kovats and Jendritzky, 2006; United States Environmental Protection Agency (U.S. EPA) et al., 2006). There are several known approaches to determining the threshold for triggering an alert. To be effective, accurate predictive capabilities must inform adequate communication and warning strategies and timely response measures (Ebi, 2005). The widespread introduction of air conditioning, improved emergency and health care services, improved weather forecasting, and the introduction of heat alert and response systems in large cities such as Toronto have helped to keep the number of heat wave-related deaths and illnesses in Canada low (Clean Air Partnership (CAP), 2004; Dolney and Sheridan, 2005). In the eastern U.S., especially in its southern areas, excess deaths from high summer temperatures have declined significantly from the 1960s to the 1990s, apparently for reasons similar to those in Canada (Davis et al., 2002).

Heat alert systems rely upon communication activities and networks as important components of a response plan. Municipal actions are largely undertaken by community-based partners, in terms of outreach to vulnerable groups. Few communities in Canada have developed full heat alert and response plans. Given the relationship between extreme heat and mortality (McGeehin and Mirabelli, 2001; Basu and Samet, 2002; Kovats and Ebi, 2006; Ebi, 2007), this may constitute a public health concern. The distribution of heat alert systems

18 See Chapter 4, Air Quality, Climate Change and Health, for more information.

in Canada is largely limited to Ontario and Quebec. A small number of communities in other regions engage in some sort of awareness-raising, such as the posting of heat-health information on community websites (Paszkowski, 2007).[19] Heat alert systems follow a similar protocol that has been developed for smog response plans. Advice is generally directed at individuals to help them reduce their exposure to heat stress. The following are the components of most systems currently in place in south-central Canada (Chiotti, 2006):

- *Monitoring*—Health department staff monitor the weather information posted by Environment Canada, usually from May 15 to September 30 each year.
- *Notification*—Health department staff are provided an advance five-day weather forecast from Environment Canada, or information regarding humidex advisories.
- *Consultation*—When necessary, Health department staff consult with the local weather office to discuss region-specific forecasts with a trained meteorologist.
- *Decision*—Based on the weather sources and conditions, the month, the heat pattern at the particular time of the season, health surveillance information and an assessment of the capacity of the system to react, the Medical Officer of Health will determine if the Region will issue a heat alert to the community (T. Kosatsky, pers. comm., November 26, 2005).
- *Activation*—If a heat alert is declared, Health Department staff will send notification to the media and community stakeholders that may be affected by extreme temperatures. Identified stakeholders, including long-term care facilities and hospitals, local shelters, municipal employees and child care centres, receive the heat alert notice. Each agency is then responsible for internal notification of its staff. Heat alert information is sent to the internal communications website contacts for posting on municipality websites. Other measures include:
  - bottled water is distributed to vulnerable people at places where they are likely to gather;
  - shelters are asked to ease their curfew rules;
  - cooling centres are opened in central locations;
  - transit tickets are issued to the homeless so they can reach cooling centres; and
  - a 12-hour heat information line is activated to answer heat-related questions.
- *Public education*—Messages to the general public reinforce individual responsibility as well as educate people. The public is encouraged to look in on vulnerable neighbours (e.g. seniors living alone) and are given information about how to provide support for hot weather illness. People without shelter and those without air conditioning are encouraged to go to air-conditioned public facilities, such as malls and libraries. Public education occurs in a variety of ways:
  - information is obtained by calling the municipality or visiting the website;
  - agencies post information on bulletin boards and are prepared to answer questions; and
  - information is provided through the media.

- *Termination*—When hot weather is no longer a health threat, the Medical Officer of Health ends the heat alert by notifying the media and participating agencies.

19 See Annex 2 for examples of municipalities and industries with heat alert systems.

- *Evaluation*—An evaluation component to the heat alert system is necessary to determine changes or additions to the plan for subsequent years.

There are different approaches worldwide and within Canada to setting thresholds for taking action on heat. For example, Toronto uses a synoptic air masses approach. This approach considers the health risks posed by a combination of several weather variables, including air temperature, dew point temperature, visibility, total cloud cover, sea level air pressure, wind speed and wind direction, in determining when to issue alerts (Angus, 2006).

Table 8.1 Number of alerts issued by Toronto Public Health, 2001–05

Year	Alerts Issued by Toronto Public Health
2001	9
2002	16
2003	6
2004	2
2005	26

Source: Angus, 2006.

In contrast, Montreal's Heat Watch Warning System is based on minimum and maximum temperature thresholds defined on the basis of temperature-related mortality for the region. Alerts are issued when both maximum temperatures are greater than 33°C and minimum temperatures are greater than 20°C, for three consecutive days (Angus, 2006). Smaller municipalities tend to rely on temperature thresholds set for larger centres or rely on Environment Canada's humidex advisories to provide additional advice to the population or trigger their respective response plan.[20]

In part, the implementation of response systems in Canada has been influenced by heat-related deaths caused by well-publicized heat waves in the U.S. (e.g. Chicago in 1995) and Western Europe (e.g. France, Italy, Germany and England in 2003). However, public health officials in some Canadian cities have examined temperature-related mortality in their own jurisdiction and identified vulnerable populations in light of future climate projections. Their concerns are also supported by a number of statistical studies demonstrating that vulnerable populations are sensitive to different temperatures and associated weather conditions (Smoyer et al., 1999, 2000). Greater understanding of temperature and health thresholds is required to inform the development of future heat alert systems to meet the needs of communities of different sizes and locations, and characterized by different vulnerable populations. The effectiveness of current heat alert systems needs to be evaluated to ensure maximum protection of populations and guide the decisions of communities in setting up appropriate systems (Angus, 2006). Key knowledge gaps exist about optimal public health interventions for reducing deaths and illnesses associated with extreme heat events (Ebi, 2005).

Current responses to increased health risks from extreme heat events have placed emphasis on adaptation measures that reduce the exposure of vulnerable populations to heat. As an adaptation option, relying exclusively on air conditioning to cope with heat waves could be risky. Any large-scale power failure, such as that of August 2003 that hit several U.S. states and much of Ontario, could leave many people physically unable to cope with unmitigated heat stress. Furthermore, the "reliance on energy-intensive technologies such as air conditioning is unsustainable and can be considered a maladaptation" (WHO, 2005).

20 A humidex advisory is issued when temperatures are expected to reach or exceed 30°C and the humidex values are expected to reach or exceed 40°C. Humidex values are intended to represent the effect that high humidity and high temperatures have on the human body. Comfort levels for humidex readings are: 20–29 (comfortable), 30–39 (varying degrees of discomfort), 40–45 (almost everyone is uncomfortable), and +45 (many types of work and exercise should be restricted) (Environment Canada, 2006). Although there is no formal definition of a heat wave, Environment Canada considers one to occur when there are three consecutive days when the maximum temperature is 32°C or higher.

Photo Credits: City of Toronto

Example of a sign indicating that a cooling shelter has been opened during an extreme heat event.

Less common in Canada are actions explicitly aimed at reducing the heat island effect (Chiotti, 2006; Paszkowski, 2007). This effect is caused by large surface areas of materials that absorb heat from the sun, such as asphalt, in combination with little vegetation to provide shade and cool the air. The urban heat island effect is responsible for making the temperature in cities 4 to 7°C higher than surrounding areas (City of Hamilton, 2006). Many measures that have been introduced to reduce the heat island effect have been driven by the need to reduce energy use in large urban centres. More recently, it is understood that these measures can offer important health benefits by reducing thermal radiation and ambient temperature in the city and offering cool shelters during extreme heat events. Such actions include planting shade trees, installing reflective roofs, optimum planning of roadways and buildings, and urban reforestation (City of Hamilton, 2006). The Green Roofs and Evergreen projects in Canada and the Cool Cities program in the U.S. indicate that the application of these measures is beginning to take place (City of Toronto, 2007; Evergreen Canada, 2007).

Case study: Heat wave simulation in Montreal

A heat wave simulation in Montreal was conducted in 2005 to test a new emergency preparedness plan. It also gauged the usefulness of such exercises in identifying gaps in preparedness and response activities related to extreme heat events. The city demonstrated an advanced level of preparedness to manage the health impacts of heat waves, and the simulation confirmed that major strides have been made in recent years in emergency planning for such events. The introduction of other events that would simulate the occurrence of cumulative impacts on the systems under evaluation was critical to this exercise. Several aspects of adaptive capacity were reviewed as part of the simulation and recommendations for improvement of current systems were made in order to further enhance the effectiveness of the plan (Rousseau, 2005).

Based upon this and other studies, actions required to ensure that plans are effective are highlighted below:

Institutions

- Heat wave emergency response plans should be well integrated with the emergency plans of the city's emergency preparedness centre and the provincial health agency.
- Community and volunteer organizations' roles should be well articulated in emergency response plans.
- A procedure to limit access to drinking water from the aqueduct in the event of water contamination (e.g. public drinking fountains) and to supply residents with drinking water should be in place.

Information sharing and skills

- It is important that the roles and responsibilities of communications officials within the city and relevant agencies are clearly articulated and that mechanisms are in place to ensure open communication between organizations at all levels (e.g. emergency preparedness centre, department of public health, provincial health agency, community organizations, Meteorological Service of Canada).

Infrastructure

- Lists of emergency shelters must be adapted to extended heat wave events and up-to-date.
- Vulnerability of the city's infrastructure critical to public health during an extended heat wave must be understood and potential failures addressed ahead of time.

8.6.3.5 Recent actions to improve adaptive capacity

To enhance our ability to reduce the health risks from air pollution, Health Canada, Environment Canada and a variety of stakeholders have been engaged in a process since 2001 to improve the Air Quality Index. A new health risk-based Air Quality Health Index has been developed. It is designed to make use of a formula that represents the combined effects of the air pollution mixture rather than using the concentration of a single pollutant as an indicator of air quality. It therefore better reflects the overall cumulative health risks associated with a more comprehensive range of air pollutants. The new index also provides explicit health messages tailored for the general population and populations at higher risk (people with pre-existing cardiovascular and respiratory disease, children, seniors). Individuals can use these messages to decide how to adapt their activities to reduce their exposure to harmful air pollution levels. Messages also include actions to reduce air pollution on both an individual and society-wide basis (Health Canada, 2006a).

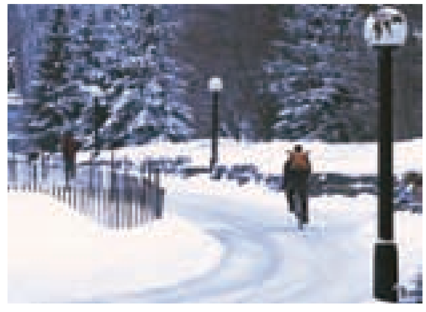
Ontario recently passed legislation on a new Clean Air Plan, which establishes new targets for sulphur dioxide (SO_2) and nitrogen oxide (NO_X) emissions from most industrial sectors by 2015, the introduction of 40 new air standards, and the implementation of a risk assessment approach to setting standards. Ontario has also made a commitment to close its coal-fired electricity generation plants; Lakeview, located just west of Toronto, was recently closed. These initiatives to reduce levels of air pollution are complemented by other actions being implemented at the regional and municipal levels, most notably the Greater Toronto Area (Canzi, 2007) and the Greater Vancouver Area (The Sustainable Region Initiative, 2005).

The Green Municipal Funds, which are managed by the Federation of Canadian Municipalities (FCM), have stimulated municipal investments in innovative environmental infrastructure projects and practices to promote cleaner air and protect the global climate. Also, 151 Canadian communities participate in the Partners for Climate Protection Program (FCM, 2007). Participants include all major urban centres across Canada that have committed to reducing GHGs and acting on climate change.

Health Canada's 'Building Heat Resilient Individuals and Communities in Canada' Initiative

In 2007 Health Canada initiated a multi-year project to reduce risks to the health of Canadians from extreme heat events. In collaboration with provincial and municipal partners, best practice guidelines for heat and response systems are being developed along with clinical guidelines for managing heat-related illnesses. Activities will be targeted at ensuring that populations most vulnerable to extreme heat events such as seniors, children, those with pre-existing diseases and the socially disadvantaged are protected.

Most major cities across Canada have developed or are developing their own climate change plans. These plans usually contain objectives and targets for GHG emission reductions for municipal corporations and the community as a whole (typically a 20 and 6% reduction, respectively, below 1990 levels by 2010). Actions are primarily transportation oriented (e.g. alternative fuels, more efficient driving practices), but also involve community plans (e.g. increased funding for cycling and pedestrian infrastructure), waste management plans (e.g. landfill recovery and cogeneration) and energy plans (e.g. greater use of renewables and improved energy efficiency). To the extent that these initiatives reduce air pollution in the affected communities and regions, they could act to offset projected future deterioration in air quality due to rising temperatures associated with climate change.[21]



21 See Chapter 4, Air Quality, Climate Change and Health, for more information, and Annex 3 for a list of Canadian municipalities with climate change programs.

In addition, in response to new research showing that vulnerable populations are sensitive to different temperatures and associated weather systems, some municipalities in central Canada (Kingston, Toronto, Region of Peel, Hamilton, Montreal, Ottawa, Region of Waterloo, Regional Municipality of Halton) have established or are considering their own heat alert systems (Chiotti, 2006).

8.6.4 Cross-Cutting Capacity to Adapt to Climate Change Health Risks

In 2005, a federal/provincial/territorial adaptation working group agreed on a National Climate Change Adaptation Framework. The Framework presents areas of potential collaboration among jurisdictions to increase Canada's capacity to adapt to climate change impacts, to recognize and reduce risks, and to identify and pursue opportunities (Natural Resources Canada (NRCan), 2005). As well, several provinces and territories have made commitments to address climate change impacts by developing climate change action plans. A number of these, including Quebec, Yukon, Ontario, Newfoundland and Labrador, and British Columbia, highlight potential health risks associated with climate change. Those developed by Quebec, Newfoundland and Labrador, and British Columbia set out specific actions to prepare for actual or expected health risks through adaptation (Government of British Columbia, 2004; Government of Newfoundland and Labrador, 2005; Government of Quebec, 2006) At the time of writing, Nunavut and Saskatchewan were developing their respective plans, both of which are expected to include a human health component. Such plans are necessary for providing the institutional foundation and policy focus, along with access to funding and partnership development, to facilitate efforts to address climate change and health risks.

The Canadian Climate Impacts and Adaptation Program, sponsored by the Government of Canada, has funded climate change adaptation research in public and private sectors and provided information to individuals, businesses and communities to assist them in making appropriate decisions about climate change adaptation (Lemmen and Warren, 2004). Several federal departments have supported research on adaptation and have participated in national impacts and adaptation assessments. Results from health research have been used to inform adaptation initiatives; for example, in the development of the health component of the Quebec climate change action plan (Government of Quebec, 2006). The health care sector is well organized with respect to the sharing of climate change adaptation information (e.g. Canadian Climate Impacts and Adaptation Research Network (C-CIARN) Health Sector) as well as internationally (collaboration of Le Centre Hospitalier universitaire de Québec with WHO) (Gosselin, 2004), in part, due to these investments.

Over the past several years, the Government of Canada has worked to enhance partnerships with national voluntary organizations through increased outreach, engagement, collaboration and capacity building. The voluntary sector is a key partner in strengthening the health of Canadians and their communities (Health Canada, 2005a). Voluntary organizations play an important role through health promotion, the development of social capital by empowering people and communities to take action, and through the provision of extensive networks of service at the community level. Organizations such as the Canadian Red Cross and the Salvation Army provide a wide range of social services to Canadians. These services are a vital component of adaptive capacity in this country. In 2003, approximately 161,000 non-profit and voluntary organizations were operating across the country. Approximately 17% of voluntary organizations were in the health and social services sectors (Statistics Canada, 2003b). In the event of a disaster, relief organizations provide emergency social services such as clothing, shelter, tracing and reunification services, and emotional support for affected individuals and communities. During heat alerts, public health officials can work with many different community-based groups (e.g. Red Cross, Salvation Army) that reach out to vulnerable populations. In Toronto, for example, more than 1,100 community agencies working with vulnerable populations are advised during a heat alert (Chiotti, 2006).

In 2005, a national collaboration among the Canadian Red Cross, the Salvation Army, St. John Ambulance and other key organizations developed a voluntary sector framework for health emergencies and a model for developing and sustaining episodic volunteers. This collaboration of key partners in the voluntary and non-governmental sectors provides opportunities for voluntary organizations to engage effectively with all levels of government on matters related to climate change and the needs of communities and vulnerable populations. This successful model is now being used to increase broader voluntary sector involvement in health emergencies related to climate change (Canadian Red Cross et al., n.d.(a), n.d.(b)).

Despite efforts in many areas to improve adaptive capacity, the 2006 report of the Commissioner of the Environment and Sustainable Development noted the absence of overall strategies and plans in federal departments to guide their work on adaptation to the effects of climate change (OAG, 2006). It found that the federal government has made limited progress in organizing its activities to obtain the information needed to identify potential impacts and address vulnerabilities. A report by The Conference Board of Canada (2007) called for a greater federal role in adaptation by:

- funding direct physical and economic research on adaptation measures;
- facilitating partnerships with other governments;
- improving data collection about the state of natural capital (e.g. forest cover, water resources) to determine the magnitude and extent of local impacts; and
- collaborating with provincial governments to review regulatory structures and to ensure that regulators pay attention to adaptation considerations.

8.6.5 Key Findings

Governments and communities in Canada have taken many actions to adapt to health risks associated with extreme weather and climate variability.

Analysis in this section demonstrates that many actions have been taken in the past to protect Canadians from health risks associated with extreme weather and climate variability, water- and food-borne contamination, air pollution and heat waves. Such actions have contributed to limiting the number of deaths from weather extremes and other health emergencies in Canada. However, the economic costs of extreme events in this country are increasing rapidly (Etkin et al., 2004), and such events continue to pose significant risks to the health and well-being of Canadians and their communities. Climate change knowledge needs to be integrated into current planning activities to adapt our current systems to the changes ahead.

Concerns exist about the effectiveness of current adaptations to health risks from current climate variability.

Gaps have been reported in measures and systems in Canada that can reduce climate-related health risks. Parliamentary reviews and other reports have raised concerns about emergency management systems which relate to government leadership, funding arrangements, communications and 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 Canadians to a range of climate-related hazards but its renewal presents 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 the state of 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 the different types of communities in Canada. In addition, measures to mitigate the urban heat island effect are limited in Canadian communities.

This analysis also found that capacity is not evenly distributed among communities in Canada. Disparities exist in the ability to plan and prepare for emergencies among cities and smaller communities and rural areas. Smaller communities and rural areas are generally engaged in fewer activities and have less capacity to adopt needed measures. This may translate into significantly less protection from disasters and public health emergencies for people living in these communities.

Recent initiatives and activities have improved the ability of governments and communities to reduce risks to health from current climate variability.
The ability of governments and communities to mitigate, prepare for and respond to a number of public health emergencies and other risks to health (e.g. smog episodes) has been improved. This improvement has taken place in response to calls to strengthen the capacity to address risks to health from environmental threats. Investments have been made from national to local levels in a range of public health activities, and government and non-governmental partners are working to improve coordination, collaboration and information sharing to provide more effective management of a variety of risks to health.

The creation of PHAC and related investments in several public health functions and services in Canada has begun to address a number of the identified concerns regarding existing capacity for addressing public health emergencies. In addition, the new National Framework for Health Emergency Management and the Voluntary Sector Framework for Health Emergencies have enhanced adaptive capacity by providing needed coordinating structures to facilitate emergency planning and response activities within and outside of government.

Although knowledge gaps about risks and vulnerabilities remain, investment in impacts and adaptation research by all levels of government and partners has built a foundation of knowledge that is now available to public health decision makers for the development of adaptation strategies. The health care sector is well organized with respect to the sharing of climate change adaptation information, but research funding and researchers dedicated to this issue are limited.

Most provinces and territories have either developed a climate change action plan that includes adaptation, or are in the process of doing so. Quebec is particularly well advanced, and has developed a slate of activities to address the health risks associated with climate change. Many provinces and territories have taken important actions to enhance emergency preparedness in communities, and have strengthened regulations governing drinking water quality. At the community level, many local authorities have developed climate change or clean air plans that support and direct programs for reducing air pollution and associated risks to health.

Presently, it is not possible to estimate the extent to which recent improvements in public health and emergency management services have protected the health of Canadians from climate-related impacts. Many of the initiatives have only recently been launched, and the very broad scope of activities makes such analysis prohibitive.

Existing gaps in public health and emergency management activities that are not addressed in the future have the potential to significantly affect the ability of Canadians to plan for and respond to climate change impacts in Canada.
Gaps in current adaptations and existing capacity to protect people from the health risks related to climate change in Canada are of particular concern if there is wide exposure to such risks or if exposure increases significantly. High exposure in this context suggests greater vulnerability of individuals and communities and requires increased adaptive efforts to reduce the health risks related to climate change. Street et al. (2005, p. 173) suggested that "the fact that most public health systems are currently taxed to their maximum and struggling to deal with emerging health problems limits their capacity to deal with the added health impacts of extreme weather and climate events." The more complex cumulative and long-term effects need to be considered as well. There is a pressing need for research related to these types of health effects, because many are indirectly induced or triggered by a number of climatic factors.

8.7 EXPOSURE TO CLIMATE-RELATED HEALTH RISKS

The following sections summarize information from previous chapters of this Assessment and other sources to document the potential direct and indirect exposure of Canadians to a range of climate-related risks. Information is also provided on how exposure might increase with climate change, where data permit. A wide range of environmental and social factors may influence human exposures and sensitivities to climate change health risks (Smit and Wandel, 2006). Many of these factors differ from region to region and even community to community. Therefore, vulnerability assessments at these levels will be required to obtain information needed to more accurately identify priority health risks and effective adaptations.

People are exposed to a range of climate-related risks

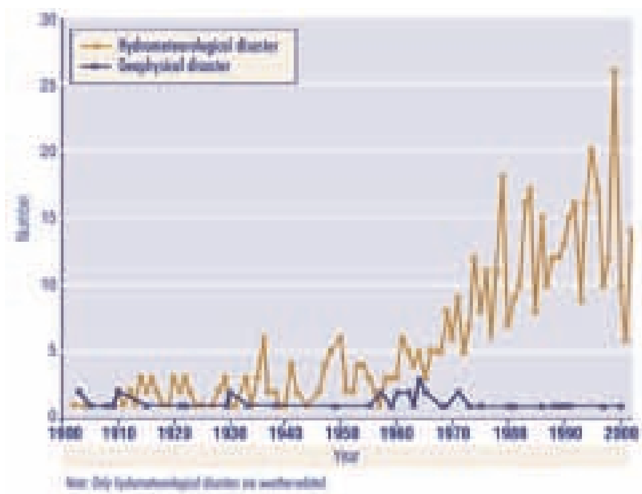
"Climate change currently contributes to the global burden of disease and premature deaths (very high confidence). Human beings are exposed to climate change through changing weather patterns (for example, more intense and frequent extreme events) and indirectly through changes in water, air, food quality and quantity, ecosystems, agriculture and economy. At this early stage the effects are small, but are projected to progressively increase in all countries and regions."

(IPCC, 2007a, p. 43).

8.7.1 Natural Hazards

Many Canadians have been exposed to natural hazards and have suffered effects on their health (e.g. dislocation). The total number of Canadians affected by natural disasters increased from 79,066 between 1984 and 1993, to 578,238 between 1994 and 2003. Single events can expose very large numbers of people to hazards. For example, the 1998 Ice Storm resulted in 4,826,586 people, or 66.9% of the general population of Quebec, being impacted by the storm (Gutman, 2007). The total number of people affected was 1,243,335 in the Montérégie region alone, the area most severely affected, and of these, 128,960 or 10.3% were people over 65 years of age (Gutman, 2007). Figure 8.1 shows the rise in the number of natural disasters in Canada over the last century.

Figure 8.1 Frequency of Natural Disasters in Canada, 1900–2002



Source: Etkin et al., 2004.

Certain areas of Canada experience specific weather events and hazards much more frequently than others. Potential exposure to individual hazards therefore varies significantly across Canada, as one would expect given the size of the country and associated variations in weather patterns, ecosystem characteristics and physical features. Table 8.2 identifies the regions in Canada most affected by specific natural hazards and weather-related extreme events.

Table 8.2 Regions in Canada affected by natural hazards

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
Wildfires 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

Note: Information for this table is drawn from Chapter 3, Vulnerabilities to Natural Hazards and Extreme Weather, which analyzed information from the Canadian Disaster Database. The table includes information from the database to highlight where most of these events 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.

This table illustrates that all provinces and territories in Canada have been affected by hazards in the past. Some hazards, such as flooding or cold waves, have affected people in communities across Canada whereas others, such as hurricanes, are a threat in only a few regions. Some hazards, such as heat waves, have been identified as particular threats for highly populated urban centres (e.g. Toronto, Montreal) whereas others, such as forest fires and avalanches, tend to affect communities that are more remote and less densely populated—although the impact of forest fires on air quality is known to be far reaching. It is also important to note that some regions and communities can be threatened by more than one hazard. Individuals living in Prairie communities are potentially exposed to heat waves, cold waves, flooding, drought, thunderstorms, hailstorms and tornadoes. This is important from a public health perspective, given the possibility of cumulative risks to health from extreme weather events that can occur in quick succession. The exposure of Canadians to climate-related hazards from a regional and population basis is currently high.

Intense rainstorms in British Columbia

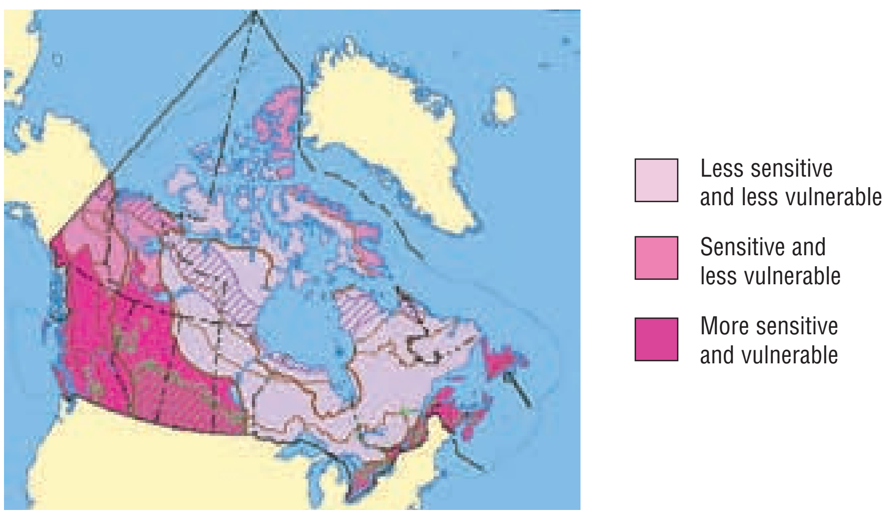
In November 2006, British Columbia experienced a number of intense rainstorms. So much rain fell that rivers in the Lower Mainland, the south coast and the southern half of Vancouver Island rose close to flood levels. Intense rains triggered mudslides, washouts and flooding. Eight communities and 200,000 people were left without power when transmission lines were damaged by a storm. The mudslides triggered by the intense rainfall contaminated drinking water sources forcing two million residents to boil their water—the widest warning in Canadian history. The warning remained in effect for 10 days for nearly one million people (Environment Canada, 2007a).

Climate change is projected to increase the frequency and intensity of specific natural hazards in Canada. More frequent extreme weather events that threaten communities with limited experience with such events in the past (e.g. greater number of heat waves) will mean increased exposure to potential health risks in the absence of effective adaptations (e.g. flood mitigation measures, urban heat island mitigation measures, further reductions in the release of air pollutants). To illustrate how the exposure of Canadians might change in the future, projections of increased flooding and forest fires under climate change conditions are described in sections 8.7.1.1 and 8.7.1.2, respectively.

8.7.1.1 Flooding

Floods have been the most commonly reported disasters in Canada (Tudor, 1997). With climate change, it is very likely that heavy participation events will become more frequent. It is also likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and greater amounts of precipitation (IPCC, 2007b). Increased frequency and magnitude of flood flows will increase the hazard to structures, buildings and humans (NRCan, 2000). Figure 8.2 highlights the regional sensitivity of rivers to predicted climate change in Canada. The most sensitive regions include the Atlantic coast and the Great Lakes and St. Lawrence Valley regions. This is a result of the shift from snowmelt to more intense rainstorms as the main source of flooding. Small streams in urban areas may pose particular hazards for people and their communities. Flows are also likely to increase in the southern Cordillera and eastern slopes of the Rocky Mountains. This will affect large Prairie streams, whereas smaller Prairie streams risk flooding from increases in thunderstorm activity (Atlas of Canada, 2007b).

Figure 8.2 Sensitivity of river regions to climate change

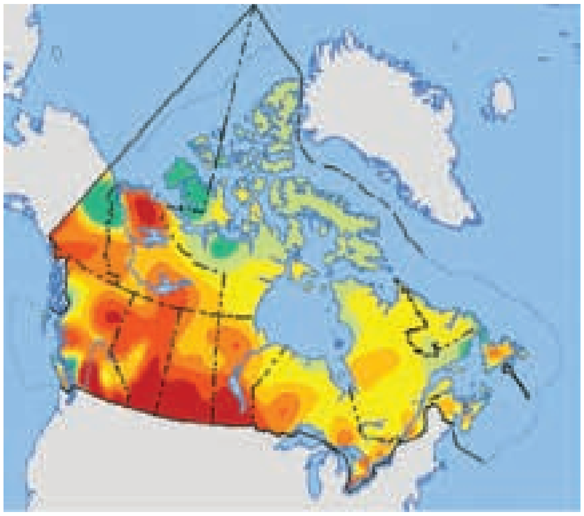


Source: Atlas of Canada, 2007b.

8.7.1.2 Forest fires

There are about 9,000 forest fires recorded annually in Canada. An average of 2.1 million hectares are burned every year, the majority being boreal forests (Nugent, 2002). Using four General Circulation Models (GCMs) to project forest fire danger levels in Canada under a warming climate, large increases in the extent of extreme fire danger and a lengthening of the fire season were found (NRCan, 2000). Figure 8.3 shows projected seasonal severity ratings across Canada in the period 2050 to 2059, based on a climate with doubled carbon dioxide (CO_2) concentrations (based on the Canadian GCM). Areas with high severity ratings are projected to expand into the central and northern parts of the Prairies, north-eastern British Columbia and south-central Yukon (Atlas of Canada, 2007a).

Figure 8.3 Projected forest fire severity level, 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, 2007a.

8.7.2 Water-, Food-, Vector- and Rodent-Borne Diseases

Canadians are currently exposed to a range of climate-sensitive infectious diseases. For example, Chapter 5, Impacts of Climate Change on Water-, Food-, Vector- and Rodent-Borne Diseases, revealed that many Canadians, particularly the young and seniors, are affected by gastrointestinal disease each year in Canada. This burden of disease is partly attributable to water sources, but it is not yet possible to determine to what extent (Charron et al., 2005). Water-borne disease outbreaks have been associated with *E. coli* O157: H7, *Campylobacter,* occasionally *Shigella* and other pathogens (Levy et al., 1998; Lee et al., 2002; Oliver et al., 2003; Charron et al., 2004; Schuster et al., 2005). *E. coli, Campylobacter* and *Salmonella* constitute the most common food-borne pathogens in Canada (PHAC, 2003).

West Nile virus, a mosquito-borne illness, was first documented in Canadian birds in 2001 (Pepperell et al., 2003). Since then, it has spread rapidly, and has been documented in all Canadian provinces and territories, except for British Columbia, Newfoundland and Labrador, Yukon, Nunavut and the Northwest Territories. Over 1,800 human cases were reported in Canada from 2002 to 2005; 46 were fatal. Cases have been concentrated in a number of urban and semi-urban areas of southern Quebec, southern Ontario and in rural populations in the Prairies (Pepperell et al., 2003; Gaulin et al., 2004).

Lyme disease currently does not affect many Canadians, although the vector *Ixodes pacificus* is widespread in British Columbia. As well, populations of *I. scapularis* can be found in southeastern Nova Scotia, southern Ontario and southeastern Manitoba (Barker and Lindsay, 2000; Ogden et al., 2005).

Hantavirus pulmonary syndrome is a rare disease in Canada, with only 36 cases being reported between 1989 and 2001 (Drebot et al., 2000). Cases have been confined to the western Canadian provinces—British Columbia, Alberta, Saskatchewan and Manitoba, with only one case being reported in Quebec (Weir, 2005). However, the presence of infected mice throughout Canada suggests that the potential for exposure to this disease exists across the country (Drebot et al., 2000).

Climate change is expected to increase the exposure of Canadians to a number of climate-sensitive water-, food-, vector- and rodent-borne diseases. Weather has been linked to a number of reported water-borne disease outbreaks in Canada.[22] Climate change may also heighten vector-borne disease risks through a variety of mechanisms, such as the development of new habitats that can support the establishment of vectors where they could not survive before, and changes in lifestyles and activities of Canadians altering their exposure to vectors (e.g. camping more often). For example, climate change may bring about higher ambient temperatures that will shorten tick life cycles, create more favourable conditions for host-seeking activity and increase tick survival (Ogden et al., 2004, 2005); this in turn would increase the risk of Lyme disease in Canada.

Climate change-related alterations in the worldwide distribution and intensity of various diseases could increase the exposure of Canadian travellers to these diseases. Global increases in endemic malaria, increased resistance to anti-malarial drug therapy, and a significant increase in global travel have resulted in thousands of cases of malaria transported into Europe and North America annually, with a few giving rise to transmission by indigenous mosquitos (Fayer, 2000). Several hundred cases of malaria are imported into Canada each year (MacLean et al., 2004).

8.7.3 Air Pollution and Extreme Heat Events

8.7.3.1 Air pollution

Many Canadians are exposed to air pollution, particularly smog. The Government of Canada estimated in 2005 that air pollution causes 5,900 premature deaths in eight Canadian cities each year (Health Canada, 2005b). The Ontario Medical Association provided similar mortality estimates, but additionally estimated that air pollution is associated with approximately 17,000 hospital admissions and 60,000 emergency room visits in Ontario every year (Ontario Medical Association, 2005). Illnesses caused or exacerbated by air pollution, such as respiratory and cardiovascular disease, will increase in prevalence as the Canadian population ages (Health Canada, 2005b). Individuals with diabetes, asthma, emphysema, heart disease and circulatory disease are at greater risk on days when air pollution is high (Health Canada, 2005b). Therefore, as the number of Canadians with pre-existing conditions increases, it can be expected that more air pollution-related deaths, hospitalizations and emergency room visits will occur. Three regions in Canada experience more episodes of elevated levels of smog than others: the southern Atlantic region, the Windsor to Quebec corridor and the Lower Fraser Valley in British Columbia (Nugent, 2002). Current exposure to smog is significant; these are highly populated regions and make up a substantial portion of Canada's total population.

Figure 8.4 shows the increase in the national seasonal average of ground-level ozone between 1990 and 2005. There is regional variation; the highest levels and most consistent increases have occurred in southern Ontario. This region, which is home to 30% of Canadians, had an increase in ozone concentrations of 17% from 1990 to 2005. Southern Quebec and Alberta also had higher ozone concentrations. Concentrations in southern Quebec increased by 15% over this time period (Government of Canada, 2007). Between 1990 and 2004, NOx and volatile organic compound (VOC) levels in urban areas decreased, likely because of improvements in fuel quality and emission control technologies for on-road vehicles (Government of Canada, 2006).

22 See Chapter 5, Impacts of Climate Change on Water-, Food-, Vector- and Rodent-Borne Diseases, for more information.

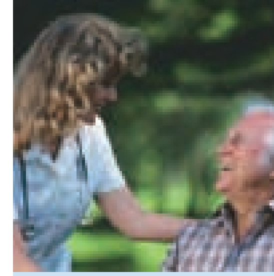
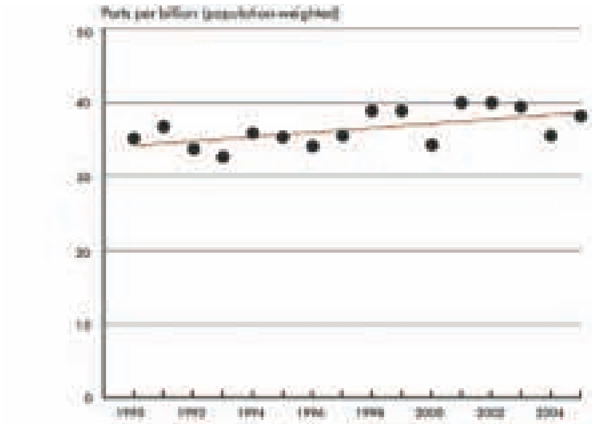


Figure 8.4 Ground-level ozone exposure indicator, Canada, 1990–2005

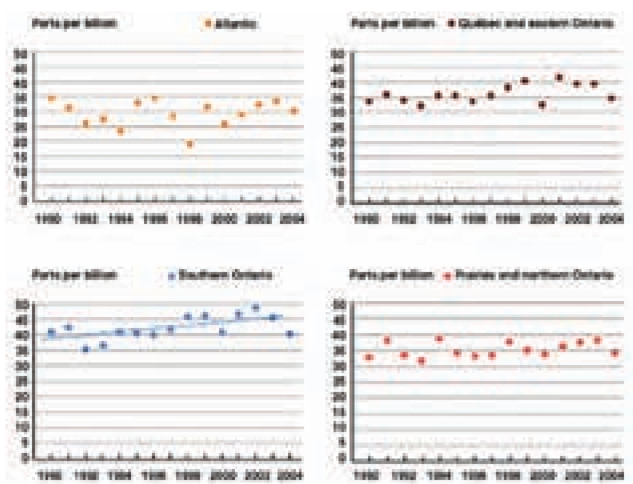


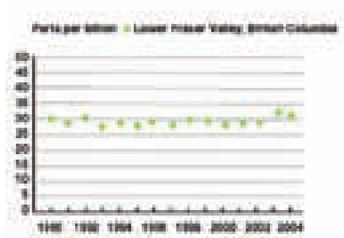
Note: The trend line represents an average rate of change of 0.8% per year. From 1990 to 2005, the indicator shows a statistically significant increase of 12% (plus or minus 10 percentage points, resulting in a possible increase ranging from 2 to 22% at a 90% confidence level). Ambient data collected from 76 monitoring stations.

Source: Government of Canada, 2007.

Warming of the global atmosphere will likely lead to regional and global changes in precipitation, cloud cover, water vapour, wind direction and wind speed, which in turn could influence the formation of air pollutants in the atmosphere.[23] The IPCC (2007a) has reported that concentrations of ground-level ozone are projected to increase over North America. Modelling results presented in Chapter 4, Air Quality, Climate Change and Health suggest that a warming of 4°C associated with climate change, without other changes in the climate or in emissions, would result in increased ozone concentrations and resulting health effects. Larger increases would be observed in the Windsor to Quebec corridor, and in the Calgary, Edmonton, Fort McMurray and Vancouver areas. Figure 8.5 shows the current regional variations in ozone trends.

Figure 8.5 Ground-level ozone indicator by region, 1990–2004





Note: The indicator is a population weighted estimate. A trendline represents the average rate of change based on the Sen method. It is shown only for the region with a statistically significant trend.

Source: Government of Canada, 2006.

23 See Chapter 4, Air Quality, Climate Change and Health, for more information.

8.7.3.2 Extreme heat events

Although heat-related hospital admissions and deaths have not been much studied in Canada, in recent years there have been frequent news reports of people suffering from heat waves and smog in cities in southern Canada. This was the case during the summer of 2005 (Canadian Broadcasting Corporation (CBC) News, 2005). Based on historical records, “hot days” (temperatures equal to or above 30°C) occur with some regularity in most parts of southern Canada. On a regional basis, the highest number of hot days tends to occur in southern Ontario and southern Quebec, although such events can also occur in Prairie cities and interior British Columbia. Table 8.3 illustrates the regional pattern of hot days and the significant increase in observed temperatures in 2002 compared with the historical norm (1961–91). In early August 2002, a hot spell broke all records across the eastern Prairies; Winnipeg had 10 hot days, including seven in a row; Regina had 11 in a row; and Val Marie had 16 consecutive days above 30°C.

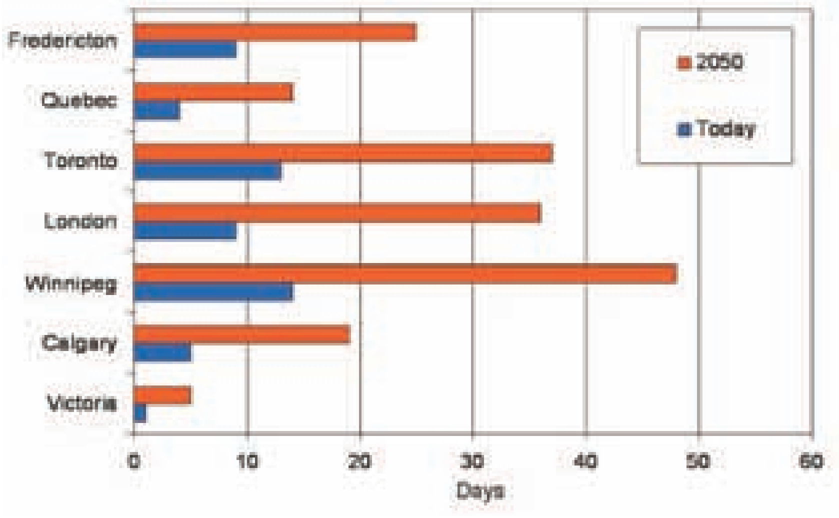
Table 8.3 Observed number of above normal “hot days” (temperatures equal to or above 30°C) for selected cities across Canada, 2002

Location	Observed	Normal
Vancouver	0	N/A
Calgary	10	5
Saskatoon	17	12
London	23	9
Toronto	34	14
Ottawa	20	11
Montreal	14	10
Moncton	7	5

Source: Environment Canada, 2002.

Although there are uncertainties associated with climate change scenarios, there is a fairly high confidence level regarding temperature projections. IPCC indicates that it is very likely that hot extremes and heat waves will continue to become more frequent (IPCC, 2007b). A recent study by Cheng et al. (2005) estimated that the number of days in south-central Canada with 3:00 p.m. temperatures ≥30°C could more than double by 2050 and triple (in some cases even quadruple) by 2080. Even larger increases have been estimated for other cities across the country by 2050. Figure 8.6 shows the current and projected number of hot days above 30°C for selected cities across Canada. Exposure to extreme heat events associated with climate change is expected to grow considerably in the future, entailing greater health risks for large numbers of Canadians living in major urban centres.

Figure 8.6 Current and projected number of hot days above 30°C for selected cities across Canada

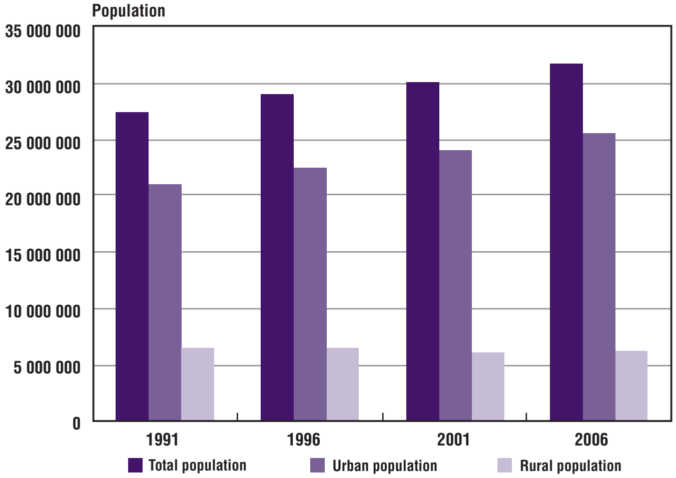


Source: Hengeveld et al., 2005.

8.7.4 Increasing Population

In the absence of increased adaptation actions, exposure to climate-related health risks will increase as Canada's population grows over the next 50 years. The population of Canada in 2004 was just under 32 million people, with almost 80% of Canadians living in urban communities (Statistics Canada, 2006). From 1991 to 2006 urban populations increased by 21% in Canada, while rural populations decreased by 2% (Government of Canada, 2007). Figure 8.7 shows the change in rural and urban populations in Canada from 1991 to 2006.

Figure 8.7 Total, urban and rural population, Canada, 1991 to 2006



Source: Government of Canada, 2007.

Under a medium-growth scenario, the population could exceed 40 million by the late 2030s, with the trend toward greater urbanization continuing. In this scenario, it would rise to 39 million in 2031 and around 42.5 million by 2056 (Statistics Canada, 2005c). More people living in large urban centres could increase exposure to specific risks to health, such as those related to more intense urban heat.

8.8 POPULATION SENSITIVITY

Gaps in the capacity to protect human health from climate change are also of concern if large segments of the population display high sensitivity to these impacts. High sensitivity implies a greater vulnerability of individuals and communities to the impacts of climate change on health. Increased adaptive efforts to reduce health risks are required in this context.

All Canadians display sensitivity to some health impacts arising from climate change. Natural disasters, extreme heat, air pollution, and water-, food-, vector- and rodent-borne diseases, all of which can be exacerbated by climate change, can affect the health of every Canadian and people living in all regions of the country. However, specific population groups, such as infants and children, seniors and those with pre-existing health conditions, can be more severely affected because of their particular physiological characteristics (Health Canada, 2005a). Sensitivity also depends on the magnitude of the threat posed by the environmental change. Some people may not be sensitive to mild changes in the environment, but are very sensitive to severe and repetitive climatic events (Health Canada, 2005a). Sensitivity is also closely related to exposure; if an individual is frequently exposed, his or her underlying sensitivity may be exacerbated. This section reviews evidence of the sensitivity of key groups within our population and examines projections of increases in these population groups, where data permit.[24] The distribution of these populations throughout Canada, along with the various attributes that underlie vulnerability, can vary widely. Future investigation of the distribution and characteristics of highly sensitive populations at regional and community levels will help to reduce climate-related health risks across Canada.

8.8.1 Seniors

Populations considered highly sensitive to climate change health impacts currently make up a significant portion of the Canadian population. Canadian seniors (age 65 and over) constituted 13% of the total population in 2005 (Statistics Canada, 2007). This group has been shown to be more sensitive than the general population to vector-borne diseases (Health Canada, 2005a), water- and food-borne contamination (Health Canada, 2005b), air pollution (Health Canada, 2003b) and heat waves (Kovats and Jendritzky, 2006; IPCC, 2007a). Many of the factors that increase sensitivity to heat waves are more pronounced in this population cohort. Risk factors for heat-related deaths and illnesses relate to (Kovats and Koppe, 2005):

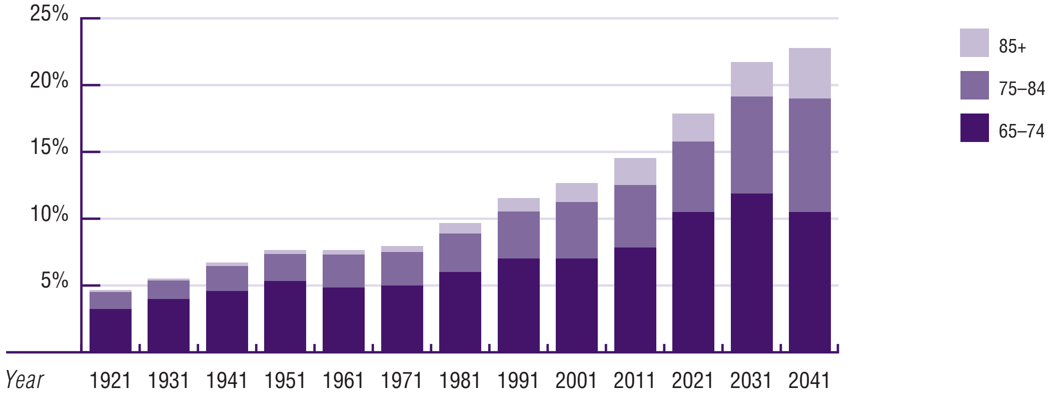
- age;
- pre-existing disease—primarily chronic respiratory or cardiovascular disease;
- social factors (e.g. living alone);
- use of certain drugs (e.g. phenothiazines, antidepressants, alcohol, diuretics);
- impaired cognition (e.g. dementia);
- housing (e.g. building type, living on high floors);
- presence and use of air conditioning in the home or residential institution; and
- physical activity—over-exertion or inactivity.

During the 2003 extreme heat event in Europe, 70% of the 14,800 excess deaths in France were persons over 75 years of age (International Federation of Red Cross and Red Crescent Societies, 2004).

24 See Chapter 7, Health Impacts of Climate Change in Canada's North, for a discussion of factors underlying the sensitivity and vulnerability of Aboriginal Canadians living in the North to the health impacts of climate change. Analysis of socially disadvantaged, disabled and immigrant populations in Canada was not conducted in this chapter and is left to further assessments.

Seniors constitute the fastest growing population group in Canada. Population projections show that population aging, which has already begun, will accelerate in 2011 when the first baby-boom cohort (born in 1946) reaches the age of 65. This rapid aging is projected to last until 2031, when seniors would account for between 23 and 25% of the total population—between 8.9 and 9.4 million people (Statistics Canada, 2007). Figure 8.8 shows the senior population by age groups, as a percentage of the total population in Canada, 1921–2041. The fastest growth is occurring among the oldest Canadians. In 2001, over 430,000 Canadians were 85 years of age or older—more than twice as many as in 1981 and more than 20 times as many as in 1921 (Health Canada, 2002a). The number of Canadians aged 85 plus will nearly double from 500,000 in 2006 to approximately 900,000 in 2026 (Statistics Canada, 2007).

Figure 8.8 Seniors by age groups, as % of the total population, Canada 1921–2041



Source: Government of Canada, 2002.

In 2003, Canadians made over 14 million visits to emergency departments in Canada. Such visits were highest for the very young and for the very old; for those over 85 years of age, 44% visited an emergency department in Ontario in 2003–04 (CIHI, 2005). In 2003, seniors accounted for a third of all acute care hospitalizations and almost 50% of all hospital days (Rotermann, 2006). Expected increases in illnesses and deaths due to the effects of climate change will place increasing pressure on the capacity of current facilities, such as hospitals, shelters and care facilities (Institute for Population Health, 2002; Carty et al., 2004; Riedel, 2004). For example, in the U.S., even with heat alert systems in place, more frequent extreme heat events are expected to increase the demand for emergency medical services and visits to emergency room facilities (U.S. EPA et al., 2006). Given projections for increased extreme heat events in Canadian cities, similar pressures on health and emergency services in Canadian communities can be expected as well.

8.8.2 Children

The environmental health field usually considers "children" to cover the period from the time of conception up to 19 years of age. This period includes defined stages during which key vulnerabilities and sensitivities are related to developmental and/or behavioural stages. Young children and developing fetuses display higher sensitivity to the many health impacts of climate variability and change (e.g. heat stress, respiratory illnesses from air pollution, water-borne diseases) because of their hand-to-mouth behaviour, proximity to the ground (where dirt and pathogens are concentrated), relatively high intake of air, water and certain foods, high surface area-to-body mass ratio, and the potential for high cumulative exposures

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over their long life expectancy (Carty et al., 2004; Health Canada, 2005b). Children age 4 and under constituted 5.3% of the Canadian population in 2005, or almost 1.8 million people (Statistics Canada, 2005c). However, by 2031 children under 4 years old are expected to decrease to 4.6% of the population (Statistics Canada, 2005c). It is also important to note that the proportion of children can vary significantly in different population groups. For example, children under 14 years old represent one third of the Aboriginal population compared to 19% in the non-Aboriginal population (Statistics Canada, 2003a). This can influence the type and delivery of programs that may be needed to protect children from climate-related hazards.

It is important to identify how childhood exposures can affect adult health; some effects may not be immediate and may manifest themselves only later in life. For example, the effect of exposure to UV radiation is cumulative; studies indicate that people who have suffered severe and frequent sunburns during childhood are at greater risk of developing melanoma later in life (Health Canada, 2006c). Prevention of children's exposure to climate-related environmental hazards may help alleviate future health care costs for adult and aging populations.

Children often depend on societal measures and parental protection to prevent exposure to climate risks. Because children, and infants in particular, must rely on the protection of parents and/or caregivers, the latter must be aware of the health risks and measures available to reduce them. Older children must also be made aware of appropriate protective practices so that they can protect themselves.

8.8.3 People with Pre-existing Illnesses

People who are chronically ill may be more sensitive to water-, food-, vector-, and rodent-borne diseases, smog and extreme heat events (Health Canada, 2005a). Chronic diseases that increase the sensitivity of individuals include cancer, cardiovascular disease (heart disease and stroke), mental illness, diabetes, asthma and chronic obstructive lung disease.

Chronic diseases are among the most common and costly health problems facing Canadians (PHAC, 2007c). In 2003, 5.7% of all Canadian adults, and nearly one in four people over 70 years of age, reported having heart problems (Heart and Stroke Foundation of Canada, 2003). The prevalence of diabetes among adult Canadians in 2000 was 5.1% (Health Canada, 2003c). In 2001, 5 serious respiratory diseases (asthma, chronic obstructive pulmonary disease, lung cancer, tuberculosis and cystic fibrosis) affected approximately 3 million Canadians, or 10% of the population (CIHI, 2006a). Asthma alone afflicted 8.5% of Canadians 12 years of age and over in 2003 (Statistics Canada, 2005a). Many chronic diseases are more prevalent in people age 65 and older in Canada, and a number of Canadians may suffer from more than one chronic disease at a time.

However, younger Canadians also suffer from chronic diseases which contributes to the number of individuals sensitive to the impacts of climate variability and change. For example, while 13% of seniors (65 years and older) had diabetes in 2000, 9% of people 55 to 64 years of age and 4% of people 45 to 54 years of age also had this disease (Statistics Canada, 2007).

Since many respiratory diseases affect adults over the age of 65, the number of people with these conditions will increase as the population ages. The prevalence of self-reported asthma is increasing (Statistics Canada, 2007). The number of deaths and, by proxy, the number of Canadians with cardiovascular disease, will also likely increase as the population ages. Canadians run a high risk of developing cardiovascular diseases: 8 out of 10 individuals have at least one of the following risk factors: smoking, physical inactivity, being overweight, high blood pressure or diabetes.[25] One in 10 has three or more. Thus, the burden of cardiovascular disease will continue for many more years.

Cancer is expected to be the leading cause of death in Canada in the next several years. The number of people to be diagnosed with cancer is expected to double between 2004 and 2020 as Canada's population grows and ages (Health Canada, 2004c). The reduction in smoking among Canadians over the last quarter century has resulted in important reductions in lung cancer in men, but insignificant time has elapsed for lung cancer rates to begin to decline in women. An improvement in dietary behaviours—Canadians are eating more fruits and vegetables—may have led to a decrease in cancers of the gastrointestinal tract. However, rates of obesity are increasing among Canadians (Statistics Canada, 2007) and this is contributing to increases in other cancers (Health Canada, 2004c).

The impact of extreme weather and climate variability on the quality of life of people living with chronic diseases is not yet well defined. Research is needed to better understand the effects of climate change on some of these diseases and the public health measures and medical treatments that are available to reduce the impacts on health. Decision makers responsible for setting standards and practices in care facilities and hospitals will not only have to plan for demographic changes and the incidence of these diseases, but also account for climatic factors that may exacerbate symptoms or even cause illnesses within populations.

25 A recent study of diabetes rates in Ontario suggested that the percentage of people with this disease is growing more rapidly than expected. About 8.8% of Ontarians over age 20 had diabetes in 2005-above the rate of 8.4% that the WHO forecasted for 2030 in industrialized countries such as Canada (CBC News, 2007).

8.9 KEY FINDINGS: THE VULNERABILITY OF CANADIANS

Canadians are currently vulnerable to climate-related health risks.

The analysis in this chapter suggests that Canadians are vulnerable to climate-related health risks. This is due to the sensitivity of groups within the population, widespread exposure to climate-related hazards, and gaps in existing adaptations and abilities to cope with the risks. With respect to natural hazards, Canada has become more vulnerable because of population growth, urbanization, an aging population and infrastructure, increasing environmental degradation and over-reliance on technologies (Environment Canada, 2003). As Etkin et al. (2004, p. i) pointed out, "Canadians are more vulnerable to natural disasters than they could or should be."

The combined effects of projected health, demographic and climate trends in Canada are expected to increase the vulnerability of Canadians in the future to climate-related health risks in the absence of effective adaptations.

As Canada's population grows and as climate change expands the geographical range, frequency and intensity of weather and climate-related hazards, individuals will increasingly be exposed to heat waves, smog episodes, storms, floods, and water-, food-, vector- and rodent-borne diseases. In addition, expected population growth and chronic disease trends indicate that the proportion of Canadians highly sensitive to the health risks of climate change will grow over the coming decades, although this may vary according to region. The number of Canadian seniors is growing dramatically. This population cohort is expected to almost double in size by 2031. The number of Canadians suffering from chronic illnesses such as heart disease, cancer and respiratory diseases is also on the rise. Consequently, more illnesses and deaths related to climate change can be expected in the absence of expanded and improved adaptations.

Climate change impacts on the health of Canadians will increase pressures on health and social services if effective adaptations are not developed and implemented.

Climate change impacts that arise out of existing vulnerabilities are expected to test the complex of infrastructures underpinning the delivery of health care and public health services in Canada (Institute for Population Health, 2002; Lemmen and Warren, 2004; Carty et al., 2004). Without effective adaptations, the costs of climate change will extend beyond the direct health impacts (e.g. increased incidence of illness, injury, and death) to include economic costs to health care and social systems (Institute for Population Health, 2002).[26]

26 In 2003, total health expenditure in Canada was $123 billion (current dollars) or $3,884 per Canadian (Statistics Canada, 2005b).

8.10 ADDRESSING CLIMATE CHANGE HEALTH RISKS AND VULNERABILITIES

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> "Without adaptation, a wide range of health impacts can be expected with the projected changes in temperature and precipitation, including deaths, diseases, and injuries caused by changes in the distribution of disease vectors and possible increases in extreme weather events such as droughts and cyclones" (Pachauri, 2005, p. xxii).

The primary objective of adaptation in the public health context is to reduce the burden of disease, injuries, disabilities, suffering and deaths (Grambsch and Menne, 2003). The preferred measures for adapting to impacts on health will be based on recognized public health strategies (Gosselin, 2004). Canada is already engaged in many adaptive actions to reduce the risks associated with current climate variability and extremes, some with greater success than others.

To a great extent, protecting Canadians from climate change will not entail the development of new programs. It will require revising, reorienting or strengthening current public health policies and practices to make them more effective and to target particularly vulnerable populations (McMichael et. al., 2003). Many of the actions that are being taken now to protect Canadians from health risks associated with air pollution (e.g. smog alerts), poor water quality (e.g. boil water advisories), infectious diseases (e.g. monitoring and surveillance), extreme weather events (e.g. preparedness and planning) and heat waves (e.g. "cooling off" locations) provide the basis for planning for climate change (Berry, 2005).

Adaptation strategies to reduce the health risks associated with climate change can have significant near- and long-term "co-benefits." Many adaptation actions reduce risks to Canadians posed by air and water pollution, infectious disease outbreaks and disasters that are not related to climate change and climate variability. In this sense, they can be considered "no-regrets" actions (Scheraga et al., 2003). For example, improved emergency management at the community level by using an all-hazards approach could help reduce health risks from toxic spills, terrorist attacks and earthquakes, in addition to those associated with extreme weather events. Similarly, preventative health measures to reduce respiratory illnesses associated with air pollution by using traffic restrictions and the development of active transportation infrastructure (e.g. bicycle paths, walking paths) can convey substantial health benefits to citizens due to less traffic congestion, more physically fit individuals and improved quality of life (Health Canada, 2005b). It is also generally acknowledged that specific adaptation measures may ultimately provide significant economic benefits for communities and governments. Relatively modest investments in disaster mitigation activities (e.g. warning systems) can help prevent deaths, widespread suffering, and the huge economic costs associated with disaster response and relief operations (International Federation of Red Cross and Red Crescent Societies, 2002).

On the other hand, current or planned policies and programs to reduce risks related to climate change may be "maladaptive" when they fail to reduce targeted risks or when they create new risks. For example, during the 1998 Ice Storm in eastern Canada, only four of a total of 28 deaths were from hypothermia; the other 24 were from carbon monoxide poisoning or injuries related to the indoor use of open flames, barbecues, or propane or kerosene heaters. Current policies could be contributing to increasing risks because they are not designed to deal with changing conditions and circumstances brought about by climate change (Barg and Swanson, 2005). It is important to gauge the effectiveness of current measures and identify where risks can arise from maladaptation.

Adaptation strategies may complement existing efforts to reduce GHG emissions aimed at addressing climate change (IPCC, 2007a). For example, changes in urban planning and building design to reduce the urban heat island effect (e.g. planting of trees, arcades and narrow streets) can prevent buildings from warming up and contribute to comfortable indoor living environments while simultaneously lowering GHG emissions through the reduced need for air conditioning (Koppe et al., 2004). Conversely, ancillary environmental and human health benefits, such as reduced local air pollution (especially fine particulate matter) and corresponding decreases in respiratory illnesses can arise from appropriately planned GHG reduction measures (Adger et al., 2005).[27] Both adaptation and GHG mitigation actions need to be employed to address climate change impacts (European Environment Agency, 2006; IPCC, 2007a).

8.10.1 Proactive Adaptation

Planning for the unexpected is one of the largest challenges posed by climate change. Adaptation to climate change health risks needs to be proactive and not reactive to prevent the largest potential impacts (WHO, 2002; Gosselin, 2004; IPCC, 2007a). The most effective and cost-efficient adaptation responses will generally be planned ahead of time rather than developed on an ad hoc basis without an integrated and comprehensive approach (Roberts et al., 2006). The precautionary principle (Lambert et al., 2003) should be used to guide the development of vulnerability assessments and adaptive public health strategies.[28] The implementation of early warning systems in anticipation of increased risks to human health from climate-related hazards is an example of application of the precautionary principle (Ebi, 2005).

There is general agreement among researchers about the types of measures needed to either improve the way current risks to health are addressed, or to plan for what a changing climate may bring. These types of measures are targeted toward both governmental and non-governmental organizations. Practical experience has shown that a combination of primary, secondary and tertiary preventative public health measures is needed to deal effectively with climate-related health risks. Types of measures include:

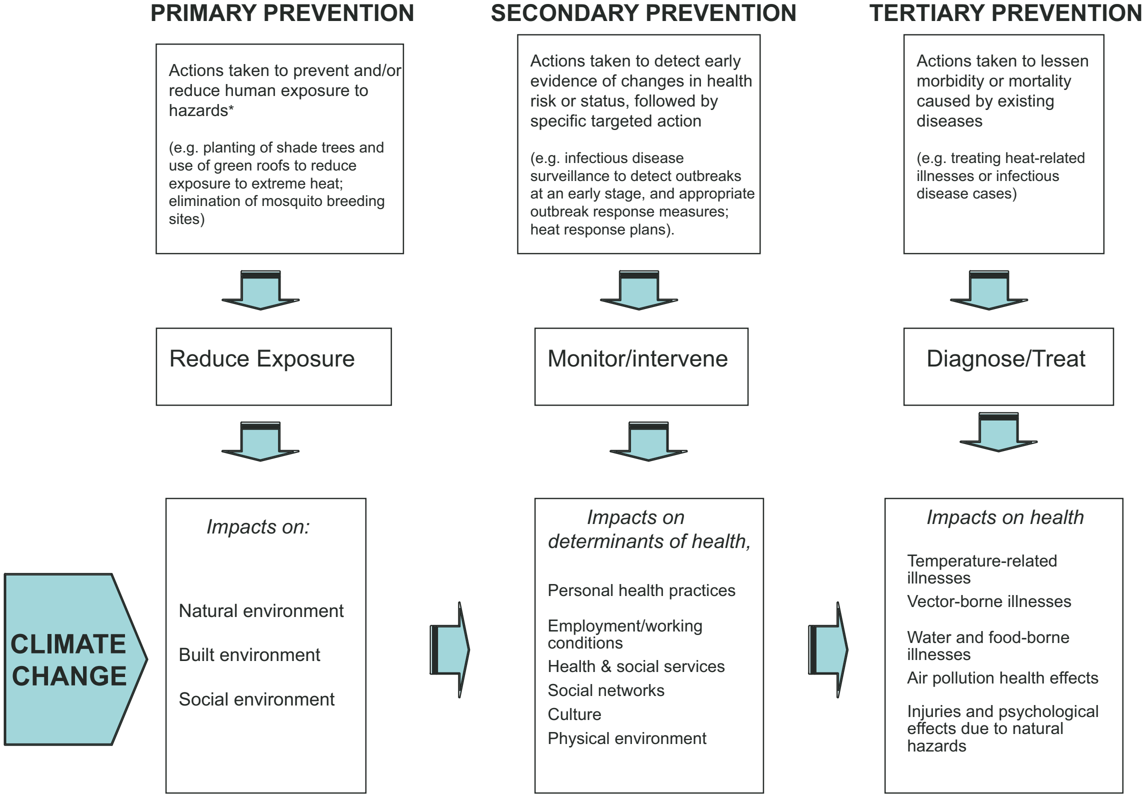
- surveillance and monitoring
- public education and outreach
- legislation
- infrastructure development
- technological and engineering innovations
- medical interventions

All types of preventative measures are needed to effectively reduce the health risks associated with climate change. However, secondary and tertiary prevention measures are both, in general, less effective than primary prevention measures and can be more expensive in the long-term (Kovats et al., 2003; The Sheltair Group, 2003).

27 The Canadian Public Health Association has called for measures to reduce GHG emissions and to address the health impacts of current energy use in Canada (CPHA, 2001c).

28 Health Canada defines the precautionary principle as "Where there are reasonable grounds to believe that exposure to an agent may cause serious or irreversible damage to human health, take cost-effective precautionary measures, even if some cause and effect relationships are not fully established scientifically. Where possible, strive to anticipate and prevent health risks rather than merely to control those that already exist" (Health Canada, 2000, p. 8).

Figure 8.9 Preventive approach to adaptation



*reduction of GHG levels (mitigation) has also been termed “primordial prevention”, or eliminating the risk itself, whereas primary prevention reduces exposure to the risk

Source: Adapted from Séguin et al. 2005.

A preventative approach (Figure 8.9) requires a sound understanding of the health risks associated with the physical and ecosystem changes related to climate change. It also requires risk-based decision support tools, a clear understanding of roles and responsibilities for adaptation, and an understanding of possible adaptation measures. Communities and regions will need to conduct their own investigations of existing vulnerabilities to health risks to identify where additional capacity is needed.[29] Vulnerability is often context specific as the conditions that interact to shape exposures, sensitivities and adaptive capacities vary among communities (Smit and Wandel, 2006). Regions and communities in Canada may have significant differences with respect to the location and size of vulnerable groups. For example, effective emergency management requires that officials have updated information about the location and number of vulnerable populations—children, seniors, people with disabilities and chronic illnesses, the socially disadvantaged—within their communities, along with knowledge of their special needs and priorities (Murphy et al., 2005).

29 Some communities or provinces have undertaken, or are in the process of undertaking, climate change impacts and adaptation assessments that include discussion about risks to human health. For example, an assessment has been conducted for Nova Scotia (DeRomilly and DeRomilly Limited et al., 2005), British Columbia (B.C. Ministry of Water, Land and Air Protection, 2002), the City of Vancouver (The Sheltair Group, 2003), the City of Hamilton (Ormond, 2004) and the City of Toronto (Ligeti et al., 2006). Most of the reports focus more on expected impacts and provide a less detailed analysis of vulnerabilities resulting from limits to adaptive capacity.

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Authorities in the health and emergency management sectors would greatly benefit from information derived from regional- and community-level assessments of vulnerability. These assessments would identify the effectiveness of key adaptation efforts currently in place in their jurisdictions. Such assessments should examine existing socio-economic and climate conditions, and those projected in the future, and develop linkages to current health impacts from which to develop adaptation strategies. They would also identify gaps that need to be addressed. Participatory impact and adaptation assessment approaches are useful for these purposes (Kovats et al., 2003; Brooks and Adger, 2004).[30] To support such activities, the next sections identify current roles and responsibilities for managing climate-related health risks in Canada and provide a list of possible adaptation options for public health officials to use to address existing health vulnerabilities to climate change.


Photo Credits: City of Winnipeg, Manitoba

Filling sandbags to combat Winnipeg's Red River Flood, 1997

8.10.2 Roles and Responsibilities for Adaptation in Canada

Many climate impact and vulnerability studies highlight lists of adaptation options but fail to investigate key decision-making processes. An important element of these processes is defining roles and responsibilities for adaptation (Grambsch and Menne, 2003). In Canada, different levels of government, including federal, provincial, territorial and municipal authorities, share the responsibility for the delivery of public health, health care and emergency social services. The allocation of responsibility for specific issues can differ significantly from one region or province/territory in Canada to another.

Municipal-level governments play a central role in reducing climate-related health risks, given their roles in providing police services, fire and ambulance services, local public health and social services, and community emergency preparedness and planning. Most emergencies in Canada are local in nature and are managed by the municipalities, or at the provincial or territorial level (PSEPC, 2006). Many municipalities are expanding their roles in these areas; however, some adaptations, such as emergency management initiatives, require that municipalities be provided with financial support, information and technical support from higher levels of government (Institute for Catastrophic Loss Reduction (ICLR) and Emergency Preparedness Canada (EPC), 1998).

Table 8.4 summarizes the key activities performed by various organizations and governments in relation to climate change health issues. Significant differences exist regarding the division of responsibilities among the federal government, provinces, territories and municipalities, so the table is illustrative in nature; some jurisdictions may not be responsible for all, or even many, of the activities listed under each health issue.[31]

30 See *Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change* (Kovats et al., 2003) for guidance on conducting assessments. Also see Chapter 2, Assessment Methods, for more information about the strengths and limitations of the methods and tools used in this Assessment.

31 For a more detailed listing of roles and responsibilities between provinces and municipalities with regard to infectious diseases, food safety and drinking water issues, see Health Canada, 2006d.

Table 8.4 Roles and responsibilities for health adaptation in Canada

Health Issue	Jurisdiction	Role
Drinking Water Quality	Municipalities	• Operation and safety of city water supplies including water testing, water treatment, water delivery and storm-water management • Drinking water quality standards and drinking water quality objectives • Sewer systems • Publish educational and advisory information on water quality • Advise on issuing boil water advisories
	Provinces/Territories	• Develop and enforce all legislation pertaining to municipal and public water supplies, including their construction and operation • Advise on policies, regulations and protocols regarding water quality inspections • Conduct inspections of municipal drinking water systems and laboratories that test drinking water • Water quality testing laboratories • Draft emergency response planning regarding water supplies • Water quality standards and watershed management • Approving designated areas for water treatment plants • Well water safety • Implementation of national guidelines for drinking water safety
	Federal Government	• Research on threats to drinking water and development of a recommended set of national guidelines for drinking water safety
Food Safety	Municipalities	• Public health inspections of food preparation and serving premises including food-processing plants, special events, retail food stores, mobile canteens • Investigate food-borne illness outbreaks • Issue permits to all food-handling establishments • Enforcement and education and training of food-handling staff • Respond to complaints made by the public • Review and approve building plans for new food-service establishments • Engage in food safety awareness activities to reduce health risks from food-borne diseases
	Provinces/Territories	• Food and safety quality regulations and legislation to ensure safety of food (e.g. toxic substances) including apiculture (bees and pollination), farming, livestock, pesticides, pest management and plant health • Register, licence and/or issue permits to food-handling establishments • Food protection, preparation and distribution programs • Animal health programs • Inspect food-processing establishments and milk plants • Education and training of food-handling staff and industry associations • Investigate and respond to complaints made by the public • Review and approve building plans for new food-service establishments • Investigate food-borne illnesses and outbreaks • Provide food safety information to the public • Note: Some provinces, such as Nova Scotia, Prince Edward Island and Newfoundland and Labrador, assume responsibility for all aspects for food safety and employ public health inspectors in this regard

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Health Issue	Jurisdiction	Role
	Federal Government	• Protect human health and the environment by minimizing the risks associated with pest control products • Set the safe residue levels for pesticides in food • Establish policies and set standards regarding the safety and nutritional value of food • Evaluate the safety, quality and effectiveness of veterinary drugs • Promote the nutritional health and well-being of Canadians • Protect the food supply from food contamination
Infectious Diseases	Municipalities	• Surveillance of communicable disease transmission at the community level • Disease prevention and control • Hospital treatment • Community-based residential, home health and public health services related to infectious disease control • Public education and awareness (e.g. West Nile virus, Lyme disease) • Public health interventions such as vaccination and screening programs, travel health • Emergency or pandemic planning
	Provinces/Territories	• Regional disease monitoring and surveillance activities through public health laboratories • Notifiable disease management guidelines • Collect, compile, analyze and publish statistics on disease incidence • Inspect waste management facilities, accommodations, workplaces, food-processing plants and various public areas • Laboratory services for detection and assessment of illness • Prevention and control • Nursing certification • Public and clinical education
	Federal Government	• Research and disease surveillance activities • Outreach and coordination with international partners (e.g. World Health Organization) • Quarantine, travel medicine and migration health programs
Air Pollution and Heat Waves	Municipalities	• Smog advisory systems and heat alert systems* • Long-term clean air and/or climate change plans that are aimed at reducing air pollution and emissions of GHGs
	Provinces/Territories	• Air quality monitoring and forecasting (e.g. air quality indices) to inform city health officials and Canadians • Temperature forecasts • Home, community and residential care for seniors who are particularly vulnerable to health risks from heat waves • Initiatives, including regulations, to improve air quality from both domestic and trans-boundary sources, such as transportation (e.g. vehicle inspection and maintenance programs), electricity generation and industrial point sources

Health Issue	Jurisdiction	Role
	Federal Government	• Scientific monitoring and technical advice for development of air quality indices and heat advisories • Air quality and temperature forecasting for smog episodes and heat alerts (e.g. humidex advisories)[†] • Initiatives, including regulations, to improve air quality from both domestic and trans-boundary sources, such as transportation, electricity generation and industrial point sources (e.g. low sulphur in gasoline and diesel fuels, Canada-United States Air Quality Agreement) • Pollution prevention plans for major emitters (e.g. base-metal smelters)
Natural Hazards	Municipalities	• Prepare and implement community emergency management plans including hazard identification and risk assessment • Health emergency services including expert medical and public health advice, management of actual or potential communicable disease outbreaks, monitoring of evacuation centres, maintaining food safety and sanitation for the community, offering counselling for stress and coping problems, assisting with emergency dental treatment, helping people with special needs, and checking the environment to make sure the air, soil and water is safe • Community design activities (e.g. land-use planning and zoning) to reduce vulnerability to hazards
	Provinces/Territories	• Emergency management legislation that supports local authorities in developing comprehensive emergency management systems that include prevention and mitigation, preparedness, response and recovery activities. It also gives local authorities special powers to prevent or limit loss of life and damage to property or the environment during a state of local emergency • Conduct environmental assessments, environmental protection and management, infrastructure upgrading and community growth management
	Federal Government	• Forecast trends in natural hazard frequency • Monitor outbreaks and global disease events • Assess public health risks during emergencies • Work toward enhancing public safety and security for Canadians in collaboration with other levels of government, community organizations and international health and security agencies • Implement federal public health rules governing laboratory safety and security, quarantine and similar issues • Bioterrorism detection, emergency health services and emergency response • Develop and implement federal and national emergency management policies, response systems and standards, including alerting the public in cooperation with provinces and territories • Work with provincial and territorial emergency management organizations to provide first responders with funds, tools and training

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Health Issue	Jurisdiction	Role
Cross-Cutting	Municipalities	• Health promotion activities that contribute to reducing health risks from climate variability and change (e.g. safe living environments, immunization information, safe food preparation, active living, etc) • Undertake, or provide support for, continued training and education of health professionals • Initiatives to reduce GHGs
	Provinces/Territories	• Facilitate local and municipal strategies to improve the health and well-being of Canadians living in their respective jurisdictions • Develop policies and strategies to focus on priority health areas of concern (e.g. water quality) • Deliver health care services • Health promotion activities that contribute to reducing health risks from climate variability and change (e.g. safe living environments, immunization information, safe food preparation, active living, etc) • Undertake, or provide support for, continued training and education of health professionals • Initiatives to reduce GHGs
	Federal Government	• National leadership for many important health issues (e.g. West Nile virus) and collaboration with international partners in efforts to protect the health of Canadians • Facilitate the development and implementation of federal/provincial initiatives (e.g. health emergency management) • Conduct intramural research and analysis about health risks and trends (e.g. human health risk assessments), develop and publish health indicators (e.g. economic burden of illness in Canada) and provide scientific and technical expertise to provinces, municipalities and health professionals (e.g. air pollution health effects) • Existing collaborative arrangements, such as the federal/provincial/territorial Committee on Health and the Environment, enhance coordination among all levels of government, ensure optimal knowledge transfer and systematic flow of scientific and policy information that cascades from federal to provincial to local government levels • Health promotion activities that can contribute to reducing health risks from climate variability and change (e.g. safe living environments, immunization information, safe food preparation, active living, etc) • Undertake, or provide support for, continued training and education of health professionals • Initiatives to reduce GHGs

Health Issue	Jurisdiction	Role
Non-Governmental Organizations		• Provide a wide range of health and social services to Canadians • Emergency management programs which provide information and emergency social services, such as clothing, shelter, tracing and reunification services, and emotional support for affected communities • Disaster relief and mitigation through information exchange and public awareness to change behaviour, education and training, access to health care delivery and personal support, research and policy development, and data collection for operational and policy planning • Help people with special needs access health services, such as dialysis, chemotherapy and respiratory aids, street youth services, assistance for homeless individuals, palliative care, services for the mentally and physically challenged, safe houses for women and children, meal services for seniors and community health centres (provide primary and health promotion services in communities)
Individuals		• Preventative measures to reduce the health risks from climate extremes and change (e.g. personal health practices such as reducing exposure to UV radiation, safe food preparation, correct hand washing, safe-driving practices, emergency preparedness plans and kits, etc) • Stay informed of important risks to health (e.g. severe weather warnings) and of measures that should be taken to protect health • Reduce GHG emissions • Testing of water quality in wells and private systems
Other Sectors		• Initiatives and programs to adapt to climate change impacts that directly or indirectly impinge on the health and well-being of a population (e.g. transportation, agriculture, industry, tourism, forestry, urban planning, insurance, etc) • Reduce GHG emissions

Notes: Responsibility for a number of public health issues in many provinces is delegated to regional-level authorities or groups that often service more that one community. For example, the province of Ontario had 36 public health units and the province of Alberta had nine regional health authorities at the time of writing. Roles and responsibilities of this kind are covered under “Municipalities” in the “Jurisdiction” column of the table.

* Some communities in Canada have undertaken such activities, although they have no formal mandate to do so.

† Environment Canada issues humidex advisories not as weather warnings but as “Special Weather Statements” (Environment Canada, 2006).

Source: Adapted from Philpot, 2006.

8.10.3 Adaptation Strategy Development and Implementation

Knowledge about 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 (Smit and Pilifosova, 2001). Researchers have developed numerous tools and approaches for assessing adaptation options. Some Canadian communities have also developed general adaptation guides (Halifax Regional Municipality, 2006; Mehdi et al., 2006). The Government of Canada, through Public Safety and Emergency Preparedness Canada, has developed a tool, *Community-wide Vulnerability and Capacity Assessment,* for carrying out a vulnerability and capacity assessment at the community level (Kuban and MacKenzie-Carey, 2001). Figure 8.10 presents a framework for describing the process of developing an adaptation strategy to reduce climate-related health risks.

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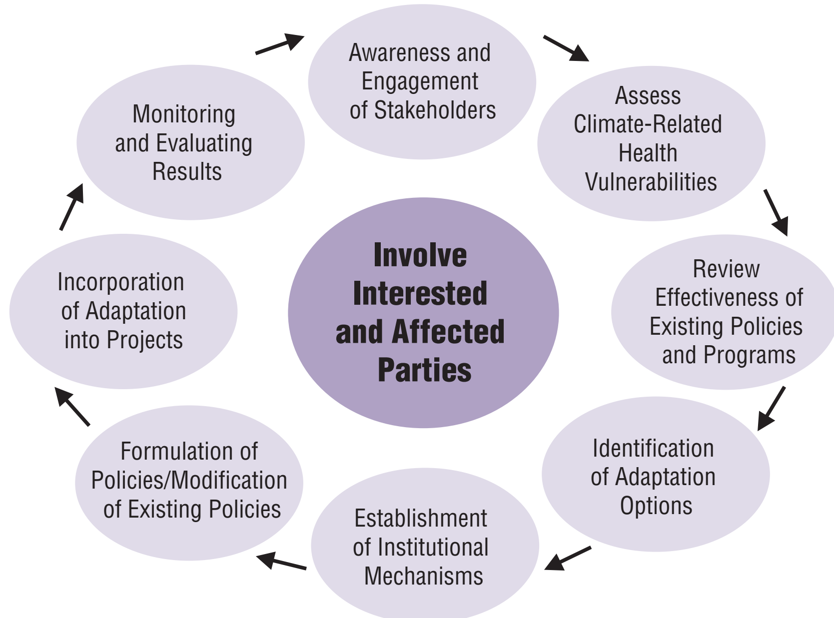
Figure 8.10 Framework for adaptation development and implementation in the health sector



Source: Adapted from Penney and Wieditz, 2007.

The framework corresponds broadly to the key steps of standard risk management frameworks that are employed in the health sector.[32] Basic steps include early engagement of stakeholders, assessing risks to health, identifying and implementing adaptation options, and monitoring and evaluating the results. A number of important considerations that are described below need to be taken into account when implementing this framework to develop effective adaptation measures to protect populations from health risks related to climate change.

8.10.3.1 Considerations for strategy development and implementation

Local and regional approaches

Smit and Wandel (2006, p. 283) indicated, "Practical initiatives that tangibly address and improve societal adaptive capacity, thereby reducing vulnerability, are commonly expected to be evident at the community scale." Therefore, efforts to develop needed adaptations to health risks associated with climate change must be tailored to the specific needs of a community or region to be successful in reducing existing vulnerabilities. In this regard, considerations of how quickly the risk must be addressed, the expected costs of adaptations, risks versus benefits of actions, and the perceptions, concerns and values of interested and affected parties (Health Canada, 2000) need to be addressed by decision makers.

Initiatives to reduce risks in urban communities (e.g. heat alerts) may not be effective public health interventions for protecting people who live in rural communities. For example, many rural communities in Canada do not have public transportation to allow people to easily get to cooling centres (if they exist) to escape extreme heat. These communities also often have a much smaller infrastructure of helping agencies (e.g. food banks) to provide assistance during extreme events (A. Berry, pers. comm., November 15, 2006).

Smaller communities may face specific challenges in preparing for and managing emergencies. Training and certification of community officials can be problematic if they are required to travel to colleges in distant large urban centres at their own personal cost. As well, many rural

32 See, for example, *Health Canada Decision-making Framework for Identifying, Assessing and Managing Health Risks* (Health Canada, 2000).

communities in some parts of Canada have become popular tourist destinations during the summer season, leading to a large influx of people at these times. For example, the community of Bayfield, Ontario, can see its population increase tenfold during the summer months from a permanent residency of 900 people. Emergencies during this period have the potential to overwhelm health and social services, creating significant planning challenges (A. Berry, pers. comm., November 15, 2006).

Multi-sectoral approach

The development of effective adaptations to climate change health risks often requires a multi-sectoral approach to planning and policy development. Protecting the health of Canadians requires effective adaptations by a range of sectors such as transportation, tourism and recreation, fisheries, forestry, agriculture, industry and energy, and municipalities. "Education and engagement of stakeholders has a primary role to play in establishing a foundation to build equitable and sustainable strategies for adapting to climate change" (European Environment Agency, 2006, p. 28). Maladaptation, or a lack of any adaptive actions at all, within any of these sectors could produce significant health risks that would need to be managed. Consequently, the health sector should aim to build close working relationships with officials in other sectors to promote awareness of the need for proactive adaptations.

The insurance industry has become active in promoting natural hazard mitigation measures; these involve actions to reduce, as much as possible, the actual physical impacts of a hazard (e.g. dams, culverts, building codes) (Murphy et al., 2005). In Canada, these activities have been promoted by the industry-funded Institute for Catastrophic Loss Reduction, created in 1997, which facilitates the development and dissemination of disaster prevention knowledge. The framework for developing adaptive strategies to reduce health risks related to climate change includes involving officials and experts from other relevant sectors in broad engagement processes; these processes require input and participation at every stage from all interested and affected parties.[33]

Mainstreaming adaptation

The adaptation literature increasingly focuses on the importance of "mainstreaming" climate change mitigation and adaptation considerations and information into existing decision-making processes, rather than creating new policies or policy instruments. This has been driven by the recognition that most adaptations are not likely to be taken because of concerns over climate change impacts alone (Smit and Wandel, 2006). The concept of mainstreaming risks related to climate change describes processes that would bring explicit consideration of climate change into current decision-making processes (Dougherty and Elasha, 2004).

In the health sector, mainstreaming entails incorporating information about climate-related health risks into existing risk management activities, and integrating efforts among different health sector partners to develop coordinated responses to these risks. Hazard assessments that take into account projected climate change impacts should be integrated into community official plans; for example, development plans could be checked against known or expected hazards to reduce risks to people and their property (McBean and Henstra, 2003). The framework for developing adaptive strategies to reduce health risks related to climate change presented earlier supports the concept of mainstreaming by highlighting the need to establish institutional mechanisms for adaptation development, and to explicitly incorporate adaptation and climate change considerations into policies and programs designed to reduce health risks. Identification of needed adaptation options to reduce health risks becomes a routine part of policy development once such considerations are mainstreamed in current activities. Table 8.5 summarizes possible adaptation measures to manage health risks related to climate change that are highlighted in the literature.

33 See *Air Quality and Climate Change Corporate Strategic Plan* (City of Hamilton, 2006) for an example of a partnership approach to address climate change impacts and adaptation issues at the community level.

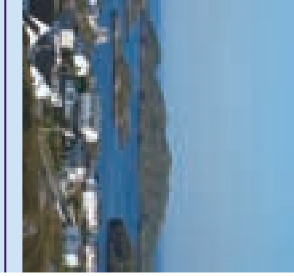
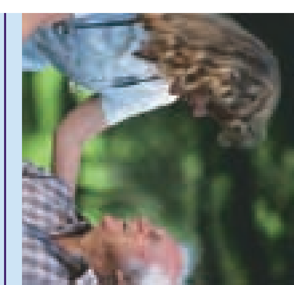


Table 8.5 Possible adaptation measures to manage health risks related to climate change

	Heat Stress	Extreme Weather Events	Infectious Diseases	Water- and Food-borne Diseases	Air Pollution
Surveillance and Monitoring	Prepare registries of vulnerable individuals (e.g. seniors) that require assistance Establish hot weather response plans and early warning systems	Prepare registries of vulnerable individuals (e.g., seniors) that require assistance Early monitoring of health outcomes from extreme weather events Enhance quantitative data on short-term and longer-term health impacts of extreme weather events	Identify most vulnerable populations Surveillance of vector populations Monitor and reporting of disease incidence	Identify most vulnerable populations Surveillance of water- and food-borne diseases Monitor and reporting of disease incidence	Identify most vulnerable populations Establish air quality monitoring systems Establish systems for reporting the impact of vehicles and other polluting sources on air quality
Public Education and Communication	Early warning systems Provide information about the health risks of heat stress and actions to protect health Provide information about measures to reduce temperatures in and around homes (e.g., planting bushes and trees)	Early warning systems Provide information about the risks of natural disasters in specific communities Provide information about actions that would reduce exposure before, during and after extreme weather events Provide information about actions to take in preparation for and during extreme weather events (e.g. stockpiling non-perishable food)	Early warning system for health professionals Provide information to residents, travellers and vulnerable populations that takes into account changes in epidemiology of infectious diseases Provide information on precautions to take to avert risks (correct hand washing, immunization)	Early warning system for health professionals Provide information to residents, travellers and vulnerable populations that takes into account changes in epidemiology of water- and food-borne diseases Provide information on precautions to take to avert risks (boiling water, safe food handling procedures)	Issue Air Quality Health Index daily to the public Provide information about actions to take to reduce exposure to air pollutants, for vulnerable groups in particular (e.g. reduce exertion levels and energy consumption, stay indoors, car pool)
Legislative	Building guidelines that make buildings more heat resistant Requirements for smart urban planning to reduce urban heat island effect	Improve land-use planning (e.g. limit development in high-risk areas such as floodplains or coasts) Foster environmental management (e.g. defensive structures to minimize flash floods, water conservation) Building guidelines to account for increasing weather severity	Quarantine laws Travel and importation of goods laws	Watershed protection laws Water quality regulations	Reduce emissions from fossil-fuel power generating stations Traffic restrictions Determine new air quality guidelines and standards to protect human health

	Heat Stress	Extreme Weather Events	Infectious Diseases	Water- and Food-borne Diseases	Air Pollution
Infrastructure Development	Provide accessible air-conditioned public facilities and shelters Provide accessible drinking fountains in outdoor public places Extend hours of cooling facilities	Identify critical and hazardous infrastructure Develop cost sharing mechanisms (e.g. insurance) for compensation to reduce post-event mental and economic stresses Improve infrastructure for effective interventions (e.g. emergency rooms and stockpiles); maintain and test public shelters and evacuation plans Maintain dams, floodplains, and storm runoff capabilities	Laboratory facilities for rapid detection of pathogens Improve infrastructure for effective interventions (e.g. emergency rooms, stockpiles)	Laboratory facilities for rapid detection of disease pathogens Upgrade water treatment, sewage and sanitation facilities to deal with more severe extreme weather Improve infrastructure for effective interventions (e.g. emergency rooms, stockpiles)	Improve public transit systems and bicycle lanes to reduce traffic-related pollution levels Incentive programs for citizens, households, communities and corporations to reduce emissions and energy consumption
Technology and Engineering	Improve urban design to reduce heat island effect (e.g. planting trees, increasing green spaces, shading conditions along streets and parking lots, pattern of subdivisions and shape, size and orientation of building lots)	Strengthen and enforce building codes and standards Develop and implement protective technologies: hard (sea walls, dams, dykes) and soft (marshes, wet lands, natural buffers, etc) to reduce the potential for floods Increase redundancy, efficiency and resilience of power supply grids	Vector control measures (e.g. reduce breeding grounds for mosquitoes and other vectors)	Disease prevention measures reflecting the latest information from Canadian and international surveillance and research organizations New technologies to improve water treatment, sewage and sanitation facilities	Promote and encourage use of alternative (clean) fuels and zero-emission vehicles
Medical Interventions	Intervention activities (e.g. "heatline") to provide information to vulnerable populations "Buddy system" to check on neighbours) Include climate change projections in health planning	Provide training to medical and emergency staff; enlist and train volunteers to be recruited during an emergency Maintain disaster management programs, including tools for local public health facilities to provide rapid health needs Include climate change projections in health planning	Develop and make available new drugs and vaccines Public immunization programs Include climate change projections in health planning	Develop and make available new drugs and other treatments Include climate change projections in health planning	Increase public health staff with a mandate to provide information on air quality health effects Include climate change projections in health planning

Source: Adapted from Chiotti et al., 2002. Includes measures from Health Canada, 2001; IPCC, 2001, 2007a.



8.10.4 Barriers to Adaptation

Many decision makers in the health sector do not yet consider adaptation to the impacts of climate change a priority issue requiring immediate attention. The fact that most Canadians are not well informed about the likely health risks associated with climate change (Carty et al., 2004) may contribute to the current approach by health officials. As well, funding for adaptation-related initiatives in Canada has been overshadowed by efforts to reduce GHGs, and has been inadequate to address existing risks (The Conference Board of Canada, 2006). Therefore, health officials may find that they must compete for resources for adaptation or share such resources with others seeking to address a variety of other public health problems.

Actions for adapting to climate-related health risks have also been hampered by an incomplete understanding of climate processes, the interacting socio-economic variables that influence climate change, and future societal responses to the expected impacts. These gaps make it difficult to project specific impacts using future climate scenarios, including the associated risks to human health. Ebi (2005, p. 49) suggested, "...there is high uncertainty about the rate and intensity of any changes in climate variability in a particular location over a specified time period, but high certainty that without adequate preparation, extreme events will lead to increased morbidity and mortality." Consequently, determining effective climate change adaptation strategies to reduce health risks can be a difficult and complex task. For example, rising sea levels and an increasing frequency of storm surges are expected to pose significant risks to property and people living in some communities of British Columbia, such as the City of Richmond. At the time of writing, that city was in the process of updating its system of dykes to accommodate changes in weather and rising sea levels. However, uncertainty about the severity of future sea level rise is making a cost-benefit analysis, as part of the efforts to update dykes in that city, difficult (Ballard and Lidster, 2006).

Scheraga et al. (2003) identified the following possible explanations for the failure to adapt effectively to health risks associated with climate variability under current climate conditions:

- failure to identify and understand factors that affect the risk and the ability of society and individuals to respond;
- limited resources available for adaptation;
- conscious decision by society not to invest scarce resources in adaptive responses; and
- perceived lack of vulnerability or perceived elimination of the threat.

Barriers to adaptation can also exist when proposed measures are either not technically feasible or their effectiveness has not been demonstrated. For example, more research needs to be conducted on the effectiveness of different response plans to manage the health risks from heat waves so that appropriate systems that respond to local needs can be developed. There may also be changes that cannot be anticipated, and adaptations to these cannot be made in advance of their occurrence. As IPCC suggests, the magnitude and timing of climate change impacts will vary with the amount and timing of climate change, and unmitigated climate change would, in the long-term, likely exceed the capacity of natural, managed and human systems to adapt (IPCC, 2007a).

Climate change is expected to affect Canada in specific geographic areas or distinct ecosystems; its impacts will not follow traditional provincial or territorial boundaries. Because provinces and territories are responsible for many aspects of environmental and health management, governments and agencies will need to collaborate when addressing vulnerabilities and developing adaptive strategies. This collaboration is needed to prevent duplication and to use resources efficiently; separate adaptive strategies may not be needed for each jurisdiction.

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8.10.5 Opportunities for Future Actions

Even in the face of the many challenges to adaptation, important opportunities exist for making progress in efforts to reduce health risks associated with climate change. Although significant gaps remain with respect to knowledge about existing vulnerabilities to the impacts, including those related to human health, research on impacts and adaptation in Canada is yielding results. A knowledge base is being developed as a result of many studies that address regional and sectoral issues, and by connecting researchers with decision makers who need to manage future risks related to climate change (OAG, 2006). Understanding of basic concerns related to health and a changing climate has increased through recent studies,[34] and this Assessment will contribute to this body of evidence.

The public health and emergency management communities can benefit from recent increases in the ability to forecast extreme weather events which have taken place over the past 30 years as more has been learned about the climate system. Environment Canada is recognized as an international leader in global climate modelling (OAG, 2006) and therefore constitutes an important source of information for future climate change adaptation work. In addition, the health care sector in Canada is well organized with respect to sharing information about climate change adaptation, both at home and internationally.

The public health field has many years of experience in reducing risks to health from environmental hazards; this experience can be drawn upon to meet the challenges posed by climate change (Ebi et al., 2005). It demonstrates that vulnerability to climate-related health risks can be reduced through appropriate adaptive actions (e.g. heat alerts, disease surveillance, health promotion activities to reduce poor health) and through efforts to build adaptive capacity.

A high level of awareness exists among public health officials in Canada about the impacts of weather and climate on human health and well-being, and about potential future risks to Canadians. This provides a strong basis for moving forward with actions to address these risks. Interest in adaptation is growing with a greater acceptance of scientific findings on climate change; reports on recent extreme weather events that have significantly impacted communities within and outside of Canada also contribute to this interest (Penney and Wieditz, 2007). Individual Canadians are capable of shifting their behavioural and architectural practices to suit climatic conditions, even as the number and geographical extent of climate-related hazards increase as the climate changes.

Canadian Red Cross: Expect the Unexpected Program

In response to the Saguenay floods of 1996, the Canadian Red Cross developed the school-based Expect the Unexpected Program. It is an example of health promotion activities carried out by a voluntary organization to reduce health risks related to natural disasters. Since 1997, this program has delivered learning activities on natural disasters and extreme weather events to over 750,000 students in 11 provinces and territories in Canada (Canadian Red Cross, 2005).

Ultimately, the opportunity to address key barriers to adaptation exists. Public health and emergency management officials and their partners can build on their past experience in addressing these types of issues through effective interventions. They can draw from the growing knowledge of health risks related to climate change and the increasing awareness of Canadians about the issues.

34 See *Climate Change and Health: Research Report* (Health Canada, 2004a).

8.11 KNOWLEDGE GAPS AND RESEARCH NEEDS

Successfully managing the health risks to Canadians arising from climate change will require more detailed assessments of vulnerabilities to existing climate variability as well as to future changes in climate. These need to take place at regional and community levels, given the broad scope of potential impacts and of possible public health responses. A number of research gaps that need to be addressed to improve adaptation development and reduce health risks have been identified in the literature (McMichael et al., 2003; Riedel, 2004). The lack of research findings related to climate change and health adaptation and adaptive capacity in Canada was a major obstacle for the assessment of capacity conducted in this chapter.

Future assessments and current efforts to manage climate-related health risks would benefit from research to improve knowledge in the areas listed below.[35]

Climate Projections

- Improved climate models and scenarios, particularly at the regional scale, to reduce the high level of uncertainty regarding possible future exposures to hazards for specific populations.
- Greater understanding of the regional distribution of health risks associated with climate change in Canada as well as differences in existing capacity to adapt (e.g. between northern and southern communities) to the future changes.

Regional and Local Assessment of Vulnerabilities

- Regional- and community-level exposure to current and future climate-related hazards that pose health risks.
- Location and attributes (e.g. perceptions and behaviours) of highly sensitive populations.
- Evaluation of emergency management plans in regions and communities that take into account climate events, climate effects and multiple stressors (e.g. cumulative impacts).
- Ability to plan for and respond to disease outbreaks and public health emergencies.
- Integrated activities to protect vulnerable populations from health risks associated with air pollution and heat waves, including efforts that may be required to take preventative measures to mitigate the health impacts of heat waves by reducing the urban heat island effect.
- Extent to which adaptive capacity is unevenly distributed among communities within regions or populations within communities. Disparities between cities and smaller communities and rural areas with respect to the ability to plan and prepare for emergencies can be significant.

35 No attempt has been made to prioritize the knowledge gaps identified here.

Adaptation Strategies and Measures

- Economic costs of the projected health impacts related to climate change.
- Economic costs of adaptation strategies (e.g. heat alert systems).
- "Best practice" adaptation measures (e.g. outreach activities, assistance to vulnerable populations, monitoring of health impacts).
- Current extent of maladaptations and their contribution to health risks from current climate variability.

- New infrastructure designs which include standards that take into account larger and potentially more damaging events expected under climate change; as current infrastructures are upgraded and replaced, engineers need new and updated climatic design values, revised codes and standards, and new methodologies to incorporate climate change considerations into engineering procedures.
- Processes and drivers of adaptation decision making and how climate change considerations can be integrated or "mainstreamed" into current health risk management practices and frameworks; level of certainty needed for public health decision makers to act; tools needed for effectively communicating this to decision makers.
- Factors that affect our current capacity to adapt at the individual, community and institutional levels, including the cumulative impacts of repeated extreme events; conditions that stimulate or act as a barrier to adaptation (e.g. institutional coordination, risk communication, participatory processes).
- Monitoring of extreme heat events, heat alerts and heat-related illnesses and deaths per year in Canadian communities.

Vulnerable Populations

- Characteristics or qualities that make specific populations more vulnerable to health risks related to climate change and the distribution of such vulnerable groups in Canada.
- Risk perception related to climate change health impacts among individual Canadians that influences capacity to adapt.
- Communications and outreach strategies for changing individual behaviours to reduce health risks (e.g. appropriate messaging during heat and smog alerts) and interventions by public health officials.

8.12 CONCLUSIONS AND RECOMMENDATIONS

8.12.1 Conclusions

This review of climate-related hazards in Canada, the exposure of people to these hazards, and the existing capacity to manage health risks reveals that Canadians are vulnerable to climate variability and weather extremes.

In the past century, we have succeeded in reducing mortality from weather extremes and other public health emergencies in Canada. However, the economic costs of extreme events in this country are rapidly increasing, as is the number of people affected by natural disasters. The fullness of the health impacts from such events is not well understood. Such events and other climate-related hazards (e.g. smog, food-, water-, vector- and rodent-borne diseases) continue to pose significant short- and long-term risks to the health and well-being of Canadians and their communities. Gaps in the adaptive capacity of governments and communities in Canada to address climate-related health risks exist. In some circumstances existing systems and measures may not be sufficient to deal with unforeseen events or to respond to the cumulative stresses arising from many events occurring simultaneously, or in rapid succession. Findings from this first assessment of adaptive capacity can inform our future research and program and policy development to enhance our current capacity to adapt to climate change.

Several factors influence the vulnerability of the Canadian population to current and future climate-related health risks:

About our population:

- All Canadians are exposed to climate-related hazards but to varying degrees. Many are at increased risk of health effects because of a greater frequency and magnitude of these hazards or due to inadequate protection or coping mechanisms.
- Health and demographic trends will increase the proportion of the population that is sensitive to the health risks associated with climate change. The proportion of seniors in Canada will grow from 13 to 25% of the population by 2031.
- Individuals play an important role in protecting themselves by responding to a range of climate-related health risks. But Canadians often do not perceive a threat from natural disasters and are generally unprepared for health emergencies.

About systems and measures in place:

- Many sectors in our society have a role to play in reducing vulnerabilities to health risks. The extent to which human health considerations are not incorporated into land-use planning, infrastructure development, emergency preparedness and mitigation, environmental management, and transportation planning increases vulnerability to climate change health impacts.
- Response systems, infrastructure and risk management approaches have been designed to respond to discrete health risks or climatic events based on past climate trends. Climate change is very likely to bring pressures that will test or exceed the limitations of these systems.

- The likelihood of cumulative impacts and the possibility of irreversible (in human-time scales) environmental changes related to climate change (e.g. loss of glaciers, desertification) suggests that there will be limits to adaptation and unavoidable impacts on health.

About our capacity to adapt:

- Public health sector and emergency management officials display concern about risks to populations from climate change but are generally not mobilized around this issue and have not accorded it sufficient attention.
- Competing budgetary priorities make it difficult to allocate sufficient resources for adaptation and preventative measures. The lack of resources is a particular constraint for small cities and communities.
- Leadership is a necessary ingredient to mobilize officials and individual Canadians to take the needed actions to protect health; many await such leadership to pave the way for future adaptations through the conduct of research and the development of needed policies and programs.

Actions to reduce the vulnerability of Canadians to current climate-related health risks are needed. Significant capacity resides in existing institutions and programs, physical infrastructures and human and financial resources that can be dedicated to protecting health and well-being. Efforts taken now to reduce risks will significantly reduce our vulnerability to the health impacts of future climate change. Well-designed adaptation strategies can have significant near- and long-term ancillary benefits, such as reduced risks to Canadians posed by air and water pollution, infectious disease outbreaks and disasters. As well, adaptation strategies (e.g. mitigation of the urban heat island effect) may support existing efforts to reduce emissions of GHGs; such measures can have significant benefits to health. Both adaptation and GHG mitigation actions need to be employed to address climate change impacts. Whether Canadians adapt successfully depends on whether existing knowledge, economic resources, skills and other resources are employed fully and effectively.

8.12.2 Recommendations

A recent review of current adaptation initiatives in select urban centres in Canada and internationally reveals that while many cities have taken action to reduce vulnerabilities to natural hazards, few have taken into account the additional pressures that climate change will create (Penney and Wieditz, 2007). This concurs with the findings of this chapter, and therefore the following recommendations are made:

Governments, communities and individuals should maintain and enhance current measures and programs to protect health from climate-related risks and incorporate climate change information into existing activities.

Sustained initiatives and activities are needed to build adaptive capacity in the health and emergency management sectors. Some systems (emergency management, public health, infrastructure, etc.) should strengthen the ability to cope with existing stresses. Many lessons have been learned from recent events in Canada that can inform the adaptation process. In addition, gaps in current adaptive capacity identified in this chapter can provide direction to decision makers for future actions.

Although the costs of adaptation can be high, the costs to health and well-being and the quality of life of Canadians will be higher if planning and implementation of adaptive responses to climate-related health risks does not occur (Health Canada, 2005a; Street et al., 2005). Experience has shown that it is less costly to invest in shoring up capacity than to repair damages from a disaster. Addressing the existing gaps in public health and emergency management activities has the potential to significantly improve the ability of Canadians to reduce health threats from future climate change in Canada.

Governments, communities and individuals should identify future vulnerabilities and plan new adaptations to increase the capacity required to manage emerging risks.
Efforts are needed to act proactively and initiate new adaptive strategies and partnerships to build the capacity to adapt that will be needed in the future. The overview of roles and responsibilities for adaptation provided in this chapter suggests that areas of responsibilities are generally well defined, although some gaps may exist for specific issues. New collaborations are required to address increases in climate-related hazards that do not respect political boundaries and that lead to events that are potentially much larger and more frequent than in the past.

Regional- and community-level assessments of health vulnerabilities are needed to identify, at the local level, where current public health and emergency management activities and those of other sectors need to be augmented to reduce risks to health. A number of approaches for conducting vulnerability assessments and for assessing adaptation options are available to public health and emergency management officials in Canada. Local and regional studies are necessary to fully understand the factors that create vulnerabilities and to guide the choice and implementation of effective risk management measures. Priority avenues of inquiry for such assessments are detailed in section 8.11 Knowledge Gaps and Research Needs of this chapter.

Health care and social services authorities need to plan for the impacts to individual and community health expected under climate change.
Health care and social services authorities in Canada should prepare for increased pressures that are expected from climate-related health risks. Demographic trends suggest that the projected increase in Canada's population and, in particular, the increase in the size of the cohort of seniors could contribute to these pressures. The health sector needs to proactively address health risks associated with climate change through its central roles in risk assessment and adaptation development (e.g. disease surveillance activities). 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 (McBean and Henstra, 2003). Developing the appropriate capacity to manage the additional stress of climate change is essential for protecting the future health of Canadians.

In conclusion, opportunities exist in Canada to protect the health and well-being of Canadians from current climate variability and future climate change. Our ability to make progress depends on our willingness and determination to plan for short- and long-term changes, and fully utilize existing capacity to reduce 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 the growing knowledge about the health risks related to climate change that Canadians face, and from previous public health experience in addressing environmental health issues with effective interventions. Early results can be achieved and supported by increasing awareness among Canadians of health risks related to a changing climate.

Chapter 8

8.13 ANNEXES

Annex 1: Types of Weather Alerts Issued by Environment Canada

Severe Thunderstorm	Tropical Storm	Rainfall	Wind	Blizzard
Tornado	Hurricane	Freezing Rain	Les Suetes	Blowing Snow
Funnel Cloud	Storm Surge	Freezing Drizzle	Wreckhouse Wind	Snowfall
Cold-Core Funnel	High Heat and Humidity	Flash Freeze	Marine Wind	Snow Squall
Landspout	Heat Wave		Dust Storm	Winter Storm
Waterspout	Humidex			Wind Chill
				Cold Wave
				Arctic Outflow
				Frost
				Multiple Weather
				Fog-Smoke
				UV
				Air Quality

Source: Adapted from Environment Canada, 2007b.

Annex 2: Heat Alert Response Plans in Canada

Municipalities		**Industry**
Capitale national (Quebec)	Laurentides	The Construction Safety Association of Ontario (Heat Response Plan)
Chaudières-Appalaches	Lanaudière	Occupational Health Clinics for Ontario Workers Inc. (Humidex Based Heat Response Plan)
City of Brampton	Laval	Occupational Health and Safety Division, Workers Compensation Board of Prince Edward Island (Guide to Heat Stress)
City of Burlington	Mauricie-Bois-Francs	Ontario Forestry Safe Workplace Association (Heat Response Plan)
City of Hamilton	Montérégie	
City of Kingston	Montreal	
City of London	Outaouais	
City of Mississauga	Region of Peel	
City of Ottawa	Regional Municipality of Halton	
City of Sudbury	Region of Waterloo	
City of Toronto	Town of Markham	
Estrie	Town of Oakville	

Annex 3: Examples of Municipal Climate Change Programs in Canada

- City of Calgary
- City of Edmonton
- City of Halifax
- City of Ottawa
- City of Sudbury
- City of Toronto
- City of Vancouver
- City of Winnipeg
- Montreal

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Chapter 9

Conclusion

Jacinthe Séguin

Contributor:
Peter Berry

Chapter 9

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Chapter 9

9.1 SUMMARY

As the federal department responsible for helping Canadians maintain and improve their health and well-being, Health Canada initiated this Assessment to advance the understanding of how climate change impacts the health and well-being of Canadians. Carried out in collaboration with several partnering organizations and individuals, it combines an investigation of population vulnerabilities to current weather and climate variability with an exploration of the effects of future climate change on natural hazards, air quality, and water-, food-, vector- and rodent-borne diseases.

Two regional health assessments were also conducted, investigating climate effects on residents of Canada's North and of the province of Quebec. These more in-depth regional assessments provide insights on the interactions of social, economic and environmental conditions that influence vulnerabilities and adaptive capacity in these regions. This Assessment also includes discussion of vulnerability and adaptive capacity to provide health sector and emergency management decision makers with information on key health risks to populations and the response capabilities needed to address immediate adaptation needs. It paves the way for future vulnerability assessments by applying these concepts in research in a practical way and providing guidance to decision makers at all levels of government for the investigation of the health effects of climate change.

This Assessment confirms that, in Canada, climate variability and climate change affect human health and well-being through different pathways that vary in their directness, temporal scale and complexity, causing or exacerbating a range of illnesses, injuries and, in extreme cases, death. Health can be affected *directly* as a result of exposure to climatic extremes (e.g. high temperatures causing dehydration and heat exhaustion) or sudden, intense changes in the environment such as a tornado or storm. Even when environmental impacts are immediate, health effects may not be apparent until prolonged or repeated environmental exposure has occurred.

Health can also be affected *indirectly* as a result of climate-induced changes in biological and geochemical systems, which create conditions favourable for the survival and replication of vectors and pathogens that can transmit diseases, or affect economic and social systems (e.g. loss of employment or property after a natural disaster resulting in stress and other illnesses). Health impacts can also occur in the presence of other risks or because of cumulative exposures to several hazards. In such cases, attribution to a specific cause or determination of synergistic effect (e.g. combined exposure to heat and poor air quality) is complex and, at times, not possible. Because the scope of effects from climate variability and climate change on health is broad, there is still much to be learned about the factors that combine with climate conditions to lead to illnesses and deaths among the Canadian population.

Climate change may convey benefits to the health and well-being of Canadians. However, the nature and scope of such benefits are not well understood. In fact, some of the benefits often cited in international literature, such as milder winter temperatures and lower winter mortality, may not be observed in Canada. For example, the analysis of temperature-related mortality in the province of Quebec revealed that current successful adaptation to very cold temperatures in that province means mortality does not peak under very cold conditions, as seen elsewhere in the world. The expected decrease in mortality due to future warmer winters is thus much reduced compared to other parts of the world. Furthermore, in the absence of further adaptations, summer mortality is expected to rise sharply under extreme heat conditions resulting in increases in average annual mortality in Quebec as the climate continues to warm. Additional research is needed

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to understand current adaptive behaviours to temperature extremes elsewhere in Canada and the expected net impacts of climate change. The focus of current research is on avoiding and mitigating health risks and on ways to increase individual and collective capacity to do so in the future. There exists capacity to address many climate-related risks in Canada. However, 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.

Accurately predicting the health impacts associated with future climate change is not currently possible, because of uncertainty about the extent and rate of expected future warming and about trends in socio-economic and demographic factors that affect the ability of Canadians to adapt to the health impacts and reduce their risks. Other sources of uncertainty in this Assessment arise from knowledge gaps related to the biological and physical processes by which climate affects health, incomplete information on population health status and health protection practices, confounding factors in attributing causes of illnesses, and difficulties inherent in estimating health impacts associated with projected future climate trends, as well as cumulative impacts.

Even if rapid reductions of greenhouse gases can be achieved in the near term, there is virtual certainty that climate change will be experienced for decades to come because of inertia in the climate system. Despite uncertainty about the nature and expected severity of future impacts and the knowledge gaps described above, the findings of this Assessment suggest the need for immediate action to buttress efforts to protect health from current climate hazards. Planning and preparing are also required to reduce or avoid potential adverse health outcomes as the climate continues to change. Together, the various chapters provide the following key findings.

9.2 KEY FINDINGS

Climate variables and climate hazards directly and indirectly impact the health and well-being of Canadians. Climate change will increase risks to health.

People in all segments of the population and regions of Canada are exposed to natural hazards and extreme weather associated with climate change (e.g. droughts, severe storms, hurricanes, extreme heat and cold events, avalanches and landslides, storm surges and floods). Knowledge of one's own community and individual vulnerabilities is imperative because the health risks vary across the country, the size of some vulnerable populations is growing, and the capacity to cope and adapt is uneven. Many factors affect Canadians' vulnerability to climate change such as where they live, their sensitivity to health impacts and their ability to protect themselves (e.g. availability of resources, knowledge of protective behaviours, and access to services).

The scope of weather-related natural hazards in Canada is quite broad. This Assessment inventoried 12 categories of weather events that can affect health. Because the Canadian Disaster Database tracks only those events that meet specific criteria related to costs, injuries and deaths, the full scope of health consequences of natural hazards reported is likely underestimated. Nevertheless, the number of Canadians affected by natural disasters has

risen in recent decades. Between 1994 and 2003, approximately 578,238 people across Canada were directly affected by natural disasters. Impacts reported include deaths, illnesses and injuries, evacuations and service interruptions (power and water outages). There is also evidence that weather events can have significant short- and long-term psychosocial impacts on the health and well-being of Canadians, but these effects are often poorly documented and under-studied in Canada. Overall, with the exception of the number of cold days, there is a projected increased risk of extreme weather and weather-related hazards in the future. Risks to human health will vary across Canada according to topography, current land use and human activity patterns, regional climate systems, and adaptation measures and systems in place to minimize health risks. Future projections of impacts from climate change include increases in drought and wildfires and certain types of storms, including more intense heavy precipitation events that can increase the risk of flash floods. Heat waves are predicted to increase in frequency and severity, with the risk of heat-related deaths being the greatest in cities.

Climate change can influence air quality as demonstrated by the modelling of the effects of an increase in global average temperature of 4°C on key air quality parameters such as ozone (O_3) and particulate matter ($PM_{2.5}$) in Canada. While results from the atmospheric modelling conducted for this Assessment focussed only on changes in temperature and biogenic emissions, this work demonstrated the need for future work to better understand the effects of different climatic conditions on air quality. Modelling of other variables that influence air quality and different warming scenarios could lead to better understanding. There is solid evidence of the health effects of air pollution in Canada and, to a more limited extent, the health effects of extreme heat and heat waves. There is a possible additive or synergistic effect on health of combined exposures to air pollution and higher temperatures in certain groups within the population, however, evidence from epidemiological studies remains insufficient at this time. Better understanding of the implications of different climatic scenarios for air quality across regions in Canada and of the effects of combined exposures to high temperatures and air pollutants, particularly for seniors and young populations, is important for deciding on the most effective measures to protect various segments of the population.

Canadians are routinely exposed to infectious diseases that are sensitive to climate variables, such as temperature and precipitation. These include diseases transmitted by insects, ticks or animals, as well as pathogens that are water-borne, food-borne, or both. There is evidence that climate variables can influence pathogen ecology, and also the activities and behaviours of Canadians which can increase their exposure to these diseases. Climate change can be expected to create favourable conditions for pathogen and vector survival where low temperatures, low rainfall or the absence of vector habitat would have previously restricted the reproduction of hosts and transmission of diseases. For example, the expansion of the range of Lyme disease's tick vector in Canada is related to higher ambient temperatures that shorten tick lifecycles; together with more favourable conditions for host-seeking activity, this would increase the geographic range of the disease. This Assessment identifies a range of water-, food-, vector- and rodent-borne diseases whose incidence may increase under changing climate conditions; however, there remain significant gaps in knowledge of the ecology of diseases, of the burden of illness from water- and food-borne illnesses, of the geographic distribution of zoonoses in wildlife and of many other factors. A systematic risk assessment that takes into account pathogenicity, estimated number of cases and incidence rates, and the likelihood that climate change will alter the risk would be useful to identify adaptation priorities. Continued multi-level collaborations are necessary to build proactive surveillance systems that are capable of identifying changing disease patterns and emerging risks in a timely fashion. This will allow public health officials to monitor population health risks and implement measures to reduce exposure and/or introduce new treatments as required.

The impacts of climate change can combine with other circumstances to increase health risks or create conditions for a disaster.

Climate change has already started to affect the environment, the economy, and infrastructures that play an important role in the health status of Canadians. The scope of these changes in Canada is documented in *From Impacts to Adaptation: Canada in a Changing Climate 2007,* recently released by the Government of Canada. The study of cumulative effects and the interaction between multiple factors determining health is challenging and still in its infancy. However, past experience in Canada and elsewhere related to extreme weather events has demonstrated that risks associated with climate change combined with individual and community vulnerabilities can lead to disasters. For this reason, it is very important to understand how well existing systems can deal with current risks, how they can withstand repeated or simultaneous events, and what factors and events combine to exacerbate vulnerabilities.

This Assessment found that Canada's expected population growth, aging population, increasing urbanization, aging of public infrastructures and trends in health status indicators may amplify the impacts of a changing climate on Canadians. In the absence of effective adaptations, the combined effects of projected health, demographic and climate trends in Canada are expected to increase the vulnerability of Canadians to the health impacts of climate change. The proportion of Canadians highly sensitive to these impacts is expected to grow, although this will vary from one region to another. The number of Canadian seniors is growing dramatically; this population cohort is expected to almost double in size by 2031 when it will account for between 23 and 25% of the population. The number of Canadians suffering from chronic illnesses, such as heart disease, cancer and respiratory disease, is also on the rise. These illnesses and their management can be rendered more difficult by climatic factors.

Regional assessments highlighted the vulnerability of specific population groups and confirmed the importance of developing adaptations tailored to local and regional needs.

This Assessment confirmed that regional-scale assessments are essential for understanding climate change and health vulnerabilities within a population as well as the factors that increase or contribute to an individual's or community's vulnerability. Compared to national-scale assessments, they require smaller data sets and can more easily take into account the context within which these risks occur. For example, when conducting a vulnerability analysis, they are better able to integrate relevant information such as local risk management practices, individual perceptions and behaviours, and socio-demographic information. In sum, regional assessments can more precisely identify the factors that influence vulnerability (e.g. exposure, sensitivity and ability to manage risks) and make specific recommendations on how to reduce risk and exposure, and how to increase the availability of response measures. Regional assessments face the same methodological challenges relating to the treatment of uncertainty as national studies. However, because they can undertake detailed assessments of current capacity to manage the risks and adaptive capacity, they can be more successful in demonstrating the need to take action despite uncertainty in the assessment of risks.

The investigation of climate change impacts on health in Quebec revealed that as average temperatures continue to increase, heat-related mortality in Quebec is expected to rise in the absence of further adaptations. A detailed survey of adaptive behaviours indicated that Quebeckers are taking many actions to reduce health risks related to heat waves and cold snaps, but that some groups have not adopted, or do not have access to, the necessary protective measures and services. It also showed that most respondents strongly support the rapid implementation of vigorous adaptive measures in many economic sectors, including mitigation of greenhouse gases.

This Assessment also advanced knowledge of public health and other local decision makers' awareness of the health risks of climate change as well as what they regard as potential barriers to adaptation. Based on a review of current measures and systems in place, adaptation to climate change is well underway in the province of Quebec and to some extent in northern Canada. However, key areas for further improvements have been identified based on the literature review and studies commissioned for this Assessment. Some of the identified deficiencies are already being addressed in the health component of the Quebec 2006–2012 action plan on climate change notably regarding surveillance systems and adaptation of health services and infrastructure.

In Canada's North, people are already reporting dramatic environmental and climatic changes and are concerned about growing risks to their health and well-being. However, climate change is not manifesting itself uniformly across the North. For example, temperature and precipitation trends vary such that regions are warming at different rates, some regions are getting drier while others are getting wetter. Awareness of climate change and its impacts is high among Northerners and local observations play an important role in gathering information about these changes. Many communities report an increase in uncharacteristic weather events, which is compromising their travel safety. Livelihoods and diets that depend on subsistence activities (i.e. hunting, fishing, gathering) already appear to be impacted in many regions, and nutritional effects from such changes are of primary concern. The importance and immediacy of these health impacts are motivating Northerners to adapt, using new and locally developed technologies, practices and innovations. However, access to support and resources for adaptation is uneven and many individuals and communities remain vulnerable to the health impacts of climate change.

Northerners are also experiencing other important societal changes that can compound the impacts of climate change. While individuals and communities are leading the way in adapting to climate change, collaborative and coordinated efforts from public and private sectors are needed to accompany local and individual efforts. Improvements in surveillance of a broad range of health impacts (e.g. water-, food-, rodent- and vector-borne diseases, ultraviolet radiation exposure, travel injuries, etc.) are required to better inform adaptation strategies, and to reduce risks to health through local interventions.

Developing the adaptive capacity of individuals, communities and governments is essential in order to address growing health risks and avoid unnecessary strain on health care and social systems.

Without effective adaptation strategies, the impacts of climate change on health are expected to increase pressure on a range of health and social service programs at all levels of government, and therefore the costs of climate change could extend beyond the health impacts (e.g. increased incidence of illness, injury, disease, death) to include increased economic costs to health care and social systems.

Chapter 9

Decision makers rely on access to material and financial resources, technology, information and skills, institutional arrangements and public health infrastructure to address health risks due to climate change. Adaptive capacity fluctuates over time, as the ability of individuals, institutions and governments within Canada to manage these health risks changes. This Assessment identifies important gaps in current capacity to address climate change health risks. In recent years, significant strides have been made in improving the ability of public health and emergency management officials to prepare for and respond to a range of climate-related hazards including extreme weather events (e.g. heat waves), air pollution, and water-, food-, vector- and rodent-borne infectious disease outbreaks. Building upon these efforts will ensure that the critical activities and partnerships necessary for reducing health risks are identified, and made the focus of future collaborative adaptation efforts.

Differences in access to social services, infrastructures and resources to reduce risks from climate change mean that the capacity to cope and adapt in Canada is uneven. Rural communities face unique challenges, such as limited resources for adaptation, less developed public infrastructures and, in some cases, isolation. Urban areas are becoming more sophisticated in their public health programming, but the complexity of issues facing them is increasing as are climate change adaptation needs.

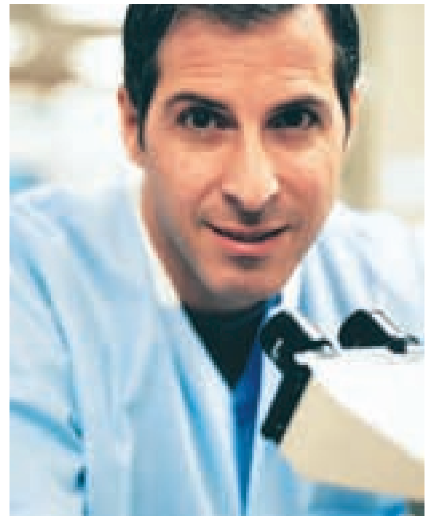
Climate change is expected to increase illnesses and deaths in Canada if public health authorities and their partners do not examine their respective vulnerabilities, and develop and implement adaptations that afford adequate protection to vulnerable groups. Regional- and community-level assessments play a useful role in identifying key health vulnerabilities in the context of other changes occurring in the population under study. They are also better positioned to assess the magnitude and urgency of key health risks, and thus can guide decisions on when and where to focus efforts. Several tools and approaches exist to assess adaptation options and best practices are beginning to emerge. These are necessary to increase decision makers' support for implementing adaptation measures and to reduce population health risks.

9.3 KNOWLEDGE GAPS

Research and knowledge from a broad range of disciplines is required to advance understanding of the effects of climate change on health and to support adaptive measures.

This Assessment highlighted the many sources of empirical data necessary for assessing the health impacts of climate change on Canadians. Surveillance and monitoring systems that public health and emergency management authorities rely upon are maintained at local, provincial and national levels and this can place limits on data aggregation and comparability. Non-empirical information, drawn from case studies and reports using local observations and personal experiences, is also important, particularly in the analysis of capacity. In each area studied, authors have identified knowledge needs that would

help to reduce uncertainty, expand the applicability of findings, identify vulnerable segments of the population and further the understanding of barriers to adaptation. Overall, knowledge needs fall under the following broad categories:



- biological and physical processes by which climate affects health;
- climate scenarios and models for estimating future health risks;
- current and future exposure of Canadians to climate-related hazards;
- identification of adaptation measures needed to reduce health risks due to climate change, including cost-benefit analyses of measures;
- perception of health risks from climate change by individual Canadians and by public and private decision makers including motivations and barriers to adaptation; and
- processes of adaptation and integration of climate change considerations into current risk management practices.

9.4 MOVING FORWARD TOGETHER

This Assessment highlighted current impacts on health from a range of climate-related hazards and the potential health vulnerabilities to climate change for specific regions, communities and populations in Canada. Health sector and emergency managemnet decision makers are beginning to draw upon existing knowledge to address the risks posed by climate change. This is being accomplished through a wide range of actions such as the development of heat alert systems, enhanced emergency management planning, and the monitoring and surveillance of emerging infectious diseases. They are developing new practices and innovative approaches and measures to reduce risks to health. Supporting the dissemination and application of best practices is central to ensuring the broad protection of Canadians.

Future investigation of the effects of climate change on health and the implementation of needed adaptations will benefit from the multidisciplinary collaboration that has begun among many research organizations. These include Canadian and international centres of expertise, such as Health Canada, the Public Health Agency of Canada, Environment Canada, Ouranos, several Canadian universities, Quebec's Institut national de santé publique du Québec, the World Health Organization and the U.S. Centers for Disease Control and Prevention. Continued investments in multidisciplinary research and policy development are necessary to build on the increased awareness about health risks associated with climate change and on the current momentum within research agencies, professional organizations and local governments in order to take action to protect the health of Canadians.

Glossary

Abrupt Climate Change

The non-linearity of the climate system may lead to abrupt climate change, sometimes called rapid climate change, abrupt events or even surprises. The term “abrupt” often refers to time scales faster than the typical time scale of the responsible forcing. Some possible abrupt events that have been proposed include a dramatic reorganization of the thermohaline circulation, rapid deglaciation and massive melting of permafrost or increases in soil respiration leading to fast changes in the carbon cycle. Others may be truly unexpected (IPCC, 2007a).

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) (IPCC, 2007a).

Adaptation Benefits

The avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures (IPCC, 2007a).

Adaptation Costs

Costs of planning, preparing for, facilitating and implementing adaptation measures, including transition costs (IPCC, 2007a).

Adaptation Mainstreaming

Integrating climate change adaptation considerations and information into policies, programs and operations at all levels of decision making rather than creating new policies or policy instruments. The goal is to make the adaptation process an essential component of existing decision-making and planning frameworks (Adapted from UNDP, 2005).

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 (IPCC, 2007b).

Aerosols

A collection of airborne solid or liquid particles with a typical size of 0.01 to 10 mm that reside in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence climate in two ways: directly through scattering and absorbing radiation, and indirectly through acting as condensation nuclei for cloud formation or modifying the optical properties and lifetime of clouds (IPCC, 2001).

Air Mass

Synoptic meteorological characterization of the entire body of air and its qualities. Air masses can be determined empirically using a combination of meteorological variables, which include temperature, relative humidity, wind speed, wind direction and barometric pressure (McMichael et al., 2003).

Air Quality Index

The AQI is a communications tool used to report upon current and near term air quality conditions. Some of the pollutants captured in currently reported Canadian AQIs are: sulphur dioxide, ozone, nitrogen dioxide, total reduced sulphur compounds, carbon monoxide and fine and coarse particulate matter. AQI advisories, and the health messages associated with them, are reported to the public and the media at set intervals each day by provinces, territories and some regional districts or municipalities. With this information, individuals can then decide how to reduce the risk to their health, as well as reduce their own personal contribution to air pollution (Health Canada, 2006).

Albedo

The fraction of solar radiation reflected by a surface or object, often expressed as a percentage. Snow-covered surfaces have a high albedo; the surface albedo of soils ranges from high to low; vegetation-covered surfaces and oceans have a low albedo. The Earth's planetary albedo varies mainly through differences in cloudiness, snow, ice, leaf area and land cover changes (IPCC, 2007a).

All-Hazards Approach

Ensures that disaster planning achieves its aims efficiently by collecting information on the full range of threats so subsequent risk management decisions can be made appropriately (Adapted from F/P/T Network on Emergency Preparedness and Response, 2004).

Anthropogenic

Resulting from or produced by human activity (IPCC, 2007a).

Atmosphere

The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen and oxygen, together with a number of trace gases such as argon, helium and radiatively active greenhouse gases such as carbon dioxide and ozone. In addition, the atmosphere contains water vapour, clouds and aerosols (McMichael et al., 2003).

AURAMS

A Unified Regional Air-quality Modelling System developed by the Meteorological Service of Canada, Environment Canada (NARSTO, 2004).

Autonomous Adaptation

Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation (IPCC, 2001).

Baseline/Reference

Any datum against which change is measured. "Current baseline" represents observable, present-day conditions. A "future baseline" is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines (IPCC, 2007a).

Botulism

Botulism is a neuroparalytic (muscle-paralyzing) disease caused by a nerve toxin produced by the bacterium *Clostridium botulinum.* There are three forms of naturally occurring botulism: food-borne botulism, caused by ingestion of pre-formed toxin; infant botulism, caused by ingestion of the bacterium which secretes toxin in the intestine; and wound botulism caused by wound infection with the bacterium (CDC, 2005b).

Brucellosis

An infectious disease caused by bacteria of the genus *Brucella,* which is transmitted to humans by ingestion of products from infected animals (i.e. unpasteurized milk products from cows, goats or pigs), by direct contact with infected animals or by inhalation of the bacterium. The symptoms include fever, headache, profuse sweating and chills (PHAC, 2003).

Campylobacter

Genus of bacteria that causes campylobacteriosis, an acute bacterial infection that attacks the digestive system. The bacterium is contracted through ingestion of undercooked meat products contaminated with *Campylobacter,* ingestion of contaminated water or close contact with infected animals. The illness is characterized by vomiting and diarrhea; globally 5 to 14% of reported cases of diarrhea are caused by infection with *Campylobacter* (PHAC, 2003).

Canada-wide Standards (PM and Ozone)

Canada-wide Standards (CWSs) refer to environmental quality and human health goals agreed upon by provinces, territories and the federal government through the Canadian Council of Ministers of the Environment. The health impacts attributed to PM and O_3 have been observed at low concentrations and the CWSs attempt to reduce concentrations of these chemicals to safer levels (CCME, 2000).

Carbon Dioxide (CO_2)

A naturally occurring gas, also a by-product of burning fossil fuels and biomass, as was well as from land use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1 (IPCC, 2001).

Cholera

An intestinal infection, caused by the bacterium *Vibrio cholerae,* which results in frequent watery stools, cramping abdominal pain and eventual collapse from dehydration. It is thought that zooplankton in cold waters may carry a large number of cholera vibrios on their bodies. Zooplankton feed by grazing on phytoplankton, which bloom with sunshine and warm conditions. Thus, a phytoplankton (algal) bloom may lead to an increase in the population of zooplankton that carry the vibrios (McMichael et al., 2003).

Climate

Climate in a narrow sense is usually defined as the average weather, also defined in statistical terms as the mean and variability of relevant variables and over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (WMO). Variables taken into account most often include surface temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (IPCC, 2007a).

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. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes (IPCC, 2007a).

Climate Model

A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. Coupled Atmosphere–Ocean General Circulation Models (AOGCMs) provide a representation of the climate system that is the most comprehensive currently available. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal and interannual climate predictions (IPCC, 2007a).

Climate Prediction (or Climate Forecast)

The result of an attempt to produce an estimate of the actual evolution of the climate in the future (e.g. at seasonal, interannual or long-term time scales) (IPCC, 2007a).

Climate Projection

A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. The use of emission/concentration/radiative forcing scenarios and attendant assumptions about, for example, future socio-economic and technological developments that may or may not be realized introduce substantial uncertainty in climate projections and distinguish them from climate predictions (IPCC, 2007a).

Climate Scenario

A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships and assumptions in radiative forcing, which has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections are often the raw material for constructing climate scenarios, but climate scenarios usually require additional information, such as about the observed current climate. A "climate change scenario" is the difference between a climate scenario and the current climate (IPCC, 2007a).

Climate Variability

Variations in the mean and other statistics (e.g. standard deviations, the occurrence of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system or to variations in natural or anthropogenic external forcing (IPCC, 2007a).

Cold Wave

Period of unusually high atmospheric-related cold stress (Environment Canada, 2002a) that may have adverse health consequences for the affected population.

Coping Ability

Short-term capacity or ability to manage an event or hazard (Smit and Wandel, 2006).

Coping Range

The variation in climatic stimuli that a system can absorb without producing significant impacts. Also known as coping ability or capacity (IPCC, 2001).

Coping Resources

The individual and community skills, materials, equipment or services that can be used to meet the demands created by an incident. Also can include municipal departments, emergency services, private companies, volunteers, and other formal and informal sources (Adapted from the F/P/T Network on Emergency Preparedness and Response, 2004).

Critical Infrastructure

Physical and information technology facilities, networks, services and assets which, if disrupted or destroyed, would have a serious impact on the health, safety, security or economic well-being of a population or the effective functioning of governments in Canada (Public Safety and Emergency Preparedness Canada (PSEPC), 2007b).

Cryosphere

The component of the climate system consisting of all snow, ice and frozen ground (including permafrost) on and beneath the surface of the Earth and ocean (IPCC, 2007a).

Cryptosporidium

A genus of parasites of the intestinal tracts of fishes, reptiles, birds and mammals. A particular species isolated in humans has been identified as *Cryptosporidium parvum.* Cryptosporidiosis, or cryptosporidium infection, is today recognized as an important opportunistic infection, especially in immunocompromised hosts (McMichael et al., 2003).

Dengue Fever

An infectious viral disease spread by mosquitoes, often called breakbone fever because it is characterized by severe pain in joints and back. Subsequent infections of the virus may lead to dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS), which may be fatal (IPCC, 2001).

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. These factors are referred to as 'determinants of health'. Key determinants 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. It is the combined influence of the determinants of health that determines health status (PHAC, 2007).

Disaster

An event that exceeds the ability of the local community to cope with the harmful effects and requires extraordinary response and recovery measures (Adapted from the F/P/T Network on Emergency Preparedness and Response, 2004).

Disaster Mitigation

Prevention of natural hazards from becoming natural disasters. It includes policies and actions taken before or after a disaster to reduce the impacts on people and property, such as building public awareness and support; development of local and regional plans for land use to prevent inappropriate development in hazardous areas; and changing building codes and standards to protect people, property and infrastructure from extremes (PSEPC, 2007a).

Diurnal Temperature Range

The difference between the maximum and minimum temperature during a day (IPCC, 2001).

Dose–Response

Association between dose and the incidence of a defined histological effect in an exposed population. Dose-response relationships are used to determine the probability of a specific outcome or disease, or risk of a disease, by extrapolating from high doses to low doses and from laboratory animals to humans, and using mathematical models that define risk as a function of exposure dose (McMichael et al., 2003).

Downscaling

A method that derives local- to regional-scale (10 to 100 km) information from larger scale models or data analyses (IPCC, 2007a).

Drought

Agricultural drought relates to moisture deficits in the topmost 1 metre or so of soil (the root zone) that affect crops; meteorological drought is mainly a prolonged deficit of precipitation; and hydrologic drought is related to below-normal streamflow, lake and groundwater levels (IPCC, 2007a).

Ecological Study

An epidemiological study which seeks to find population- or community-level associations between exposure and the occurrence of disease (Coggon et al., 1997).

Ecosystem

The interactive system formed from all living organisms and their abiotic (physical and chemical) environment within a given area. Ecosystems cover a hierarchy of spatial scales and can comprise the entire globe, communities of plants and animals corresponding to specific environmental conditions at the continental scale or small, well circumscribed systems such as a small pond (IPCC, 2007a).

Ecosystem Approach (Ecosystem-Based Management)

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It applies appropriate scientific methodologies focussed on the essential structure, processes, functions and interactions among organisms and their environment, and recognizes that humans, with their cultural diversity, are an integral component of many ecosystems. The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. Priority targets are conservation of biodiversity and of the ecosystem structures and functioning, in order to maintain ecosystem services (IPCC, 2007a).

Ecumene

Generally refers to land where people have made their permanent home, and to all work areas that are considered occupied and used for any economic purpose (Statistics Canada, 2007).

El Niño-Southern Oscillation

The term "El Niño" was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, but now refers to a basin-wide warming of the tropical Pacific east of the dateline. This oceanic event is associated with fluctuation of a global-scale tropical and subtropical surface pressure pattern, in an event called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of 2 to about 7 years, is collectively known as El Niño-Southern Oscillation, or ENSO. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. This event has great impact on the wind, sea surface temperature and precipitation patterns in the tropical Pacific, with effects throughout the Pacific region and in many other parts of the world, through global teleconnections. The cold phase of ENSO is called La Niña (IPCC, 2007a).

Emergency

Serious mishaps that involve more people, as victims and responders, than accidents, but do not overwhelm the community to the point of being a disaster (Adapted from the F/P/T Network on Emergency Preparedness and Response, 2004).

Emergency Mandate

Organizations with an emergency mandate consist of those with emergency relief services as part of their constitutional mission and/or their established tradition of community service delivery (Canadian Red Cross et al., n.d.).

Emergency Response

Actions taken in anticipation of, during and immediately after an emergency to ensure that its effects are minimized and that people affected are given immediate relief and support (Canadian Red Cross et al., n.d.).

Emission Scenario

A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g. greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (e.g. demographic and socio-economic development, technological change) and their key relationships. Concentration scenarios, derived from emission scenarios, are used as input to a climate model to compute climate projections. Since 1992, IPCC has published two series of emission scenarios, most recently in the IPCC *Special Report on Emission Scenarios* (Nakicenovic and Swart, 2000; IPCC, 2007a).

Epidemiology

The science of public health and preventative medicine that studies the distribution and determinants of health-related states or events in specific populations, and that applies study findings to control and/or mitigate health problems (Coggon et al., 1997).

Escherichia coli (E. coli)

A bacterium that produces infection characterized by acute bloody diarrhea and abdominal cramps. Food-borne transmission occurs via contaminated meat or produce and unpasteurized products. Water-borne transmission occurs through swimming in contaminated bodies of water or drinking inadequately chlorinated water (CDC, 2005b), as was the case with the widely reported *E. coli* outbreak in Walkerton, Ontario, in 2000.

Evaporation

The process by which a liquid becomes a gas (IPCC, 2001).

Evapotranspiration

The combined process of water evaporation from the Earth's surface and transpiration from vegetation (IPCC, 2007a).

Exposure

The amount of a factor to which a group or individual was exposed; sometimes contrasted with dose (the quantity of material entering an exposed person). Dose is not the same as exposure (McMichael et al., 2003).

Extirpation

The disappearance of a species from part of its range; local extinction (IPCC, 2007a).

Extreme Event

An occurrence that can cause severe damage within a community, including property destruction, personal injury and death (Adapted from the F/P/T Network on Emergency Preparedness and Response, 2004).

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 (IPCC, 2007a).

Feedback

An interaction mechanism between processes in a system, which results when an initial process triggers changes in a second process and that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it (IPCC, 2007a).

Food-Borne Diseases

Diseases that are infectious, parasitic or toxic in nature and that are acquired through the ingestion of contaminated food (CDC, 2005a).

Food-Bourne Illnesses

See food-borne diseases.

Food Security

A situation that exists when people have secure access to sufficient amounts of safe and nutritious food for normal growth, development and an active and healthy life. Food insecurity may be caused by the unavailability of food, insufficient purchasing power, inappropriate distribution or inadequate use of food at the household level (IPCC, 2007a).

Gastroenteritis

Inflammation of the stomach and small and large intestines. Viral gastroenteritis is an infection caused by a variety of viruses that results in vomiting or diarrhea. The pathogens that cause gastroenteritis may be spread through direct or indirect contact with an infected individual, as well as through the ingestion of contaminated food or beverages (CDC, 2005b).

General Circulation Model

A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity (i.e. for any one component or combination of components a hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions; the extent to which physical, chemical or biological processes are explicitly represented; or the level at which empirical parameterizations are involved) (IPCC, 2001).

Giardia

A protozoan parasite that causes giardiasis, also known as beaver fever. Symptoms include chronic diarrhea and abdominal cramps. Transmission occurs person-to-person where personal hygiene may be poor, or through the ingestion of *Giardia* cysts in fecally contaminated water or food (PHAC, 2003).

Glacier

A mass of land ice flowing downhill (by internal deformation and sliding at the base) and constrained by the surrounding topography (e.g. the sides of a valley or surrounding peaks); the bedrock topography is the major influence on the dynamics and surface slope of a glacier. A glacier is maintained by accumulation of snow at high altitudes, balanced by melting at low altitudes or discharge into the sea (IPCC, 2001).

Global Positioning System (GPS)

A hand-held radio navigation system that allows land, sea and airborne users to determine their exact location, velocity and time 24 hours a day, in all weather conditions, anywhere in the world (McMichael et al., 2003).

Greenhouse Effect

The process in which the absorption of infrared radiation by the atmosphere warms the Earth. In common parlance, the term "greenhouse effect" may be used to refer either to the natural greenhouse effect, due to naturally occurring greenhouse gases, or to the enhanced (anthropogenic) greenhouse effect, which results from gases emitted as a result of human activities (IPCC, 2007a).

Greenhouse Gas (GHG)

Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. A number of entirely human-made greenhouse gases in the atmosphere exist, such as the halocarbons and other chlorine- and bromine-containing substances (IPCC, 2007a).

Ground-Level Ozone (O_3)

Ground-level (tropospheric) ozone (O_3) is a colorless and highly irritating gas that forms just above the earth's surface when nitrogen oxides (NOx) and volatile organic compounds (VOCs) react in sunlight and stagnant air. Exposure to O_3 has been linked to premature mortality and a range of morbidity health end-points such as hospital admissions and asthma symptom days, as well as negative impacts on vegetation and synthetic materials (Environment Canada, 2006b). *See also ozone.*

Hantavirus

A virus in the family Bunyaviridae that causes a type of haemorrhagic fever. It is thought that humans catch the disease mainly from infected rodents, either through direct contact with the animals or by inhaling or ingesting dust that contains their dried urine (IPCC, 2001).

Hazard

The potential for a negative interaction between extreme events (of a natural or technological origin) and the vulnerable parts of the population. Three factors combine to create a hazard: the events that can impact on a community, the vulnerability of a population to such impacts, and the resources of the community to cope with those impacts (Adapted from the F/P/T Network on Emergency Preparedness and Response, 2004).

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 (IPCC, 2001).

Heat Wave

A period of unusually high atmospheric-related heat stress (Environment Canada, 2002a) that may have adverse health consequences for the affected population. Environment Canada considers a heat wave to occur when there are 3 consecutive days when the maximum temperature is 32°C or higher.

Humidex Advisory

Advisory issued by Environment Canada when temperatures are expected to reach or exceed 30°C and the humidex values are expected to exceed 40°C. Humidex values are intended to represent the effect that high humidity and high temperatures have on the human body. Comfort levels for humidex readings are: 20–29 (comfortable), 30–39 (varying degrees of discomfort), 40–45 (almost everyone is uncomfortable), and +45 (many types of work and exercise should be restricted) (Environment Canada, 2006a).

Ice Dam

An accumulation of broken river or sea ice caught in a narrow channel. Also known as an ice jam (IPCC, 2001).

Impact

The adverse and beneficial effects of climate change (and variability) on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts: potential impacts are those that may occur given a projected change in climate, without considering adaptation; residual impacts are the impacts of climate change that would occur after adaptation is taken into account (IPCC, 2007a).

Infectious Diseases

Any disease that can be transmitted from one person to another. This may occur by direct physical contact, by common handling of an object that has picked up infective organisms, through a disease carrier, or by spread of infected droplets coughed or exhaled into the air (IPCC, 2001).

Infrastructure

The basic equipment, utilities, productive enterprises, installations and services essential for the development, operation and growth of an organization, city or nation (IPCC, 2001).

Intergovernmental Panel on Climate Change (IPCC)

A panel established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988 to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. It has three working groups (climate science; vulnerability, impacts and adaptation; mitigation) and a task force (on national greenhouse gas inventories) (IPCC, 2007a).

Invasive Species

An introduced species that invades natural habitats (IPCC, 2001).

Ixodes scapularis

Hard tick belonging to the family Ixodidae. These organisms transmit Lyme disease, a zoonotic bacterial infection. *See also Lyme disease* (McMichael et al., 2003).

Landslide

A mass of material that has slipped downhill by gravity, often assisted by water when the material is saturated; rapid movement of a mass of soil, rock or debris down a slope (IPCC, 2001).

Legionella

See Legionnaire's disease.

Legionnaire's Disease

The more severe form of legionellosis infection, caused by the bacterium *Legionella pneumophila.* Symptoms are consistent with pneumonia, and include fever, chills and cough. Infection occurs through the inhalation of mist or vapour contaminated with the bacterium, which thrives in hot-water environments like those found in hot tubs, hot water tanks, or parts of the air conditioning systems in large buildings (CDC, 2005b).

Leptospirosis

Bacterial infection of humans by the genus *Leptospira.* Symptoms include high fever, jaundice, severe muscular pains and vomiting. Transmission is associated with contact with infected animals or water contaminated with rat urine. Also known as Weil's disease (McMichael et al., 2003).

Literature Review

A comprehensive survey of publications in a specific field of study or related to a particular line of research, usually in the form of a list of references or an in-depth review of key works. The first section of most research articles is usually devoted to a review of the previously published literature on the topic addressed in the article (Kovats et al., 2003).

Lyme Disease

A zoonotic bacterial infection caused by the spirochaete *Borrelia burgdoferi* and transmitted by hard ticks of the genus *Ixodes*. The main animal reservoir hosts for Lyme disease are wild deer as well as domesticated pets (McMichael et al., 2003).

Maladaptation

Any deliberate adjustments in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead (IPCC, 2001).

Malaria

Endemic or epidemic parasitic disease caused by four species of the protozoan genus *Plasmodium* that are transmitted to humans by the bite of female *Anopheles* mosquitoes. Disease is characterized by high fever attacks and systemic disorders and is responsible for approximately two million deaths every year, 90% of which occur in Sub-Saharan Africa. Malaria is the most serious vector-borne disease in the world (McMichael et al., 2003).

Meta-Analysis

The process of using statistical methods to combine the results of different independent studies (McMichael et al., 2003).

Methane

A hydrocarbon that is a greenhouse gas produced through anaerobic (without oxygen) decomposition of waste in landfills, animal digestion, decomposition of animal wastes, coal production and incomplete fossil-fuel combustion. It is one of the six gases to be mitigated under the Kyoto Protocol (WHO, 2003).

Microclimate

In climatology: localized climate, incorporating physical processes in the atmospheric boundary layer. The boundary layer is the lowest 100 to 200 m of the atmosphere and the part of the troposphere that is directly influenced by the Earth's surface. For example, atmospheric humidity is influenced by vegetation, ambient air temperatures by buildings and roads etc. In ecology: climatic conditions in the environmental space occupied by a species, a community of species or an ecosystem. For example, on mountain slopes, temperatures experienced by plants differ depending on the direction of the slope. Similarly, in forests, air temperature varies according to canopy cover and height. In many cases, such differentials are crucial for species survival and longevity (McMichael et al., 2003).

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 (IPCC, 2001).

Morbidity

Rate of occurrence of disease or other health disorder within a population, taking account of the age-specific morbidity rates. Health outcomes include chronic disease incidence/prevalence, rates of hospitalization, primary care consultations, disability-days (i.e. days when absent from work) and prevalence of symptoms (IPCC, 2001).

Mortality

Rate of occurrence of death within a population within a specified time period; calculation of mortality takes account of age-specific death rates, and can thus yield measures of life expectancy and the extent of premature death (IPCC, 2001).

National Framework for Health Emergency Management

In 2001, the Federal, Provincial and Territorial Ministers of Health recognized the necessity for a more integrated and coordinated strategic plan for emergency management in the health and social services sectors across Canada. The Deputy Ministers of Health, through the Advisory Committee on Population Health and Health Security (ACPHHS) and the Federal/Provincial/Territorial Networks for Emergency Preparedness and Response, tasked the Council of Health Emergency Management Directors (CHEMD) to develop a pan-Canadian framework for health emergency management. A key outcome was the development of the National Framework for Health Emergency Management, which provides a set of guiding principles for the development of an integrated and comprehensive health emergency management system in Canada(F/P/T Network on Emergency Preparedness and Response, 2004).

Nitrous Oxide (N_2O)

A powerful greenhouse gas emitted through soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production and biomass burning. One of the six greenhouse gases to be curbed under the *Kyoto Protocol* (McMichael et al., 2003).

Non-Market Impacts

Impacts that affect ecosystems or human welfare, but that are not directly linked to market transactions (e.g. an increased risk of premature death) (IPCC, 2001).

"No Regrets" Policy

A policy that would generate net social benefits whether or not there is anthropogenic climate change (IPCC, 2001).

North Atlantic Oscillation (NAO)

The North Atlantic Oscillation consists of opposing variations of barometric pressure near Iceland and near the Azores. On average, a westerly current, between the Icelandic low pressure area and the Azores high pressure area, carries cyclones with their associated frontal systems toward Europe. However, the pressure difference between Iceland and the Azores fluctuates on time scales of days to decades, and can be reversed at times (IPCC, 2001).

Ozone (O_3)

Ozone, the triatomic form of oxygen, is a gaseous atmospheric constituent. In the troposphere, it is created both naturally and by photochemical reactions involving gases resulting from human activities (photochemical smog). In high concentrations, tropospheric ozone can be harmful to a wide range of living organisms. Tropospheric ozone acts as a greenhouse gas. In the stratosphere, ozone is created by the interaction between solar ultraviolet radiation and molecular oxygen. Stratospheric ozone plays a decisive role in the stratospheric radiative balance. Depletion of the stratospheric ozone, due to chemical reactions that may be enhanced by climate change, results in an increased ground-level flux of ultraviolet (UV) B radiation (IPCC, 2001). *See also ground-level ozone.*

Pandemic

Epidemic occurring over a very wide area, crossing international boundaries and usually affecting a large number of people (McMichael et al., 2003).

Particulate Matter (PM)

Very small solid exhaust particles emitted during the combustion of fossil and biomass fuels. Particulates may consist of a wide variety of substances. Of greatest concern for health are particulates of less than or equal to 2.5 micrometres in diameter, usually designated as $PM_{2.5}$ (IPCC, 2001).

Parts Per Million (ppm)

Parts per million; unit of concentration often used when measuring levels of pollutants in air, water, body fluids, etc. One ppm is one part in one million by volume (McMichael et al., 2003).

Pathogen

An agent that causes disease, such as bacteria, viruses, algae, fungi and protozoa (Health Canada, 2007).

Permafrost

Perennially frozen ground that occurs wherever the temperature remains below 0°C for many years (IPCC, 2001).

Phenology

The study of natural phenomena that recur periodically (e.g. development stages, migration) and their relation to climate and seasonal changes (IPCC, 2007a).

Policy Instruments

The means to address a problem and achieve desired policy goals that governments can use to change socio-economic structures, and individual and collective behaviours. Instruments include provision of information, voluntary guidelines and codes and standards, regulations, and market-based mechanisms (e.g. emissions trading schemes, water pricing and allocation schemes) (UNDP, 2005).

Population Health

A measure of the health status of populations, proposed during the 1990s to selectively replace the use of the terms "human health," which is more restrictive, and public health which also encompasses preventative and curative measures and infrastructures (McMichael et al., 2003).

Glossary

Precautionary Principle

Where there are reasonable grounds to believe that exposure to an agent may cause serious or irreversible damage to human health, decision makers should take cost-effective precautionary measures, even if some cause and effect relationships are not fully established scientifically. Where possible, strive to anticipate and prevent health risks rather than merely control those that already exist (Health Canada, 2000).

Preparedness

Developing and readying response and recovery actions to increase the community's ability to respond to future impacts (Adapted from the F/P/T Network on Emergency Preparedness and Response, 2004).

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 (F/P/T Network on Emergency Preparedness and Response, 2004).

Proactive Adaptation

Adaptation that takes place before impacts of climate change are observed. Also referred to as anticipatory adaptation (IPCC, 2007a).

Rabies

Rabies is a viral disease of mammals often transmitted through the bite of an infected animal. There is a vaccine for the rabies virus, which affects the central nervous system. Early symptoms are non-specific and include fever, headache and malaise, and later symptoms are neurological in nature. Death usually occurs within days of the onset of symptoms (CDC, 2005b).

Recovery

Actions taken after a disaster to restore critical systems and return a community to pre-disaster conditions which involves the physical, social and economic components of the community (F/P/T Network on Emergency Preparedness and Response, 2004).

Recurrence Interval

Also called return period, it is the average time until the next occurrence of a defined event. When the time to the next occurrence has a geometric distribution, the return period is equal to the inverse of probability of the event occurring in the next time period, that is, $T = 1/P$, where T is the return period, in number of time intervals, and P is the probability of the next event's occurrence in a given time interval (AMS, 2000).

Reinsurance

The transfer of a portion of primary insurance risks to a secondary tier of insurers (reinsurers); essentially "insurance for insurers" (IPCC, 2001).

Resilience

Amount of change a system can undergo without changing state (IPCC, 2001).

Resource-Reliant Communities

Resource reliance is a measure of the relative importance of a resource sector (or sectors) to a particular community, specifically in relation to the employment income directly generated by the exploitation, processing and (in some cases) distribution of resources. Based on 2001 Census information and for comparative analysis, categories of resource reliant communities range from "moderately reliant" (30-49.9% of employment income derives from resource activity) to "solely reliant" (80% and above) (Atlas of Canada, 2006).

Response to Natural Hazards

Actions taken immediately before, during and after a disaster to protect people and property and to enhance recovery, such as emergency public communication, search and rescue, and medical assistance (PSEPC, n.d.).

Risk

Risk refers to the uncertainty that surrounds future events and outcomes. It is the level of exposure to uncertainties that an organization must understand and effectively manage. Risk is the expression of the likelihood of a future event occurring as well as its potential to influence the achievement of an organization's objectives (Health Canada, 2005).

Risk Management

Risk management is about making decisions involving uncertain future situations. Risk management is the systematic process – the practices and procedures – that an organization uses to manage the risks it faces. It is about setting a preferred course of action under uncertainty by identifying, assessing, understanding, acting on and communicating risk issues (Health Canada, 2005).

Rodent-Borne Disease

Diseases transmitted by rodents through close contact with humans, either indirectly or directly. Diseases can be spread indirectly to humans by way of ticks, mites and fleas that transmit the infection to humans after feeding on infected rodents. Direct transmission includes bite wounds, consuming food or water that is contaminated with rodent feces, coming into contact with surface water contaminated with rodent urine, or by breathing in germs that may be present in rodent urine or droppings that have been stirred into the air (CDC, 2006).

Salmonella

A group of bacteria that cause acute infectious disease with sudden onset of abdominal pain, diarrhea, nausea and vomiting. Transmission occurs by ingestion of contaminated foods, contact with infected animals (i.e. reptiles and birds), or fecal-oral person-to-person transmission. Most persons recover without treatment (PHAC, 2003).

Scenario

A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline (IPCC, 2007a).

Sea Ice

Any form of ice found at sea that has originated from the freezing of sea water. Sea ice may be discontinuous pieces (ice floes) moved on the ocean surface by wind and currents (pack ice), or a motionless sheet attached to the coast (land-fast ice). Sea ice less than 1 year old is called first-year ice. Multi-year ice is sea ice that has survived at least one summer melt season (IPCC, 2007a).

Sea Level Rise

An increase in the mean level of the ocean. Eustatic sea level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. In areas subject to rapid land level uplift, relative sea level can fall (IPCC, 2007a).

Sensitivity

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC, 2007a).

Shigella

Family of bacteria that cause shigellosis in humans, which is characterized by fever, stomach cramps and diarrhea that is often bloody. Transmission of *Shigella* occurs through ingestion of contaminated food, by swimming in or drinking contaminated water, or through fecal-oral person-to-person transmission (CDC, 2005b).

Social Capital

The aggregate of actual or potential resources that can be mobilized through social relationships and membership in social networks (Nahapiet and Ghoshal, 1998, as cited in Resilience Alliance, 2007).

SRES Scenarios

The storylines and associated population, Gross Domestic Product (GDP) and emissions scenarios associated with the *Special Report on Emissions Scenarios* (SRES) (Nakicenovic et al., 2000), and the resulting climate change and sea-level rise scenarios. Four families of socio-economic scenarios (A1, A2, B1 and B2) represent different world futures in two distinct dimensions: a focus on economic versus environmental concerns and global versus regional development patterns (IPCC, 2007a).

Stakeholder

A person or an organization that has a legitimate interest in a project or entity, or would be affected by a particular decision (IPCC, 2007a).

Storm Surge

The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place (IPCC, 2007a).

Stratosphere

Highly stratified region of atmosphere above the troposphere extending from about 10 km (ranging from 9 km in high latitudes to 16 km in the tropics on average) to about 50 km (IPCC, 2001).

Surge Capacity

Refers to a system's ability to rapidly expand beyond normal services to meet the increased demand for qualified personnel, and services in the event of large-scale emergencies or disasters (USDHHS, n.d.).

Sustainable Development

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (IPCC, 2001).

Synoptic

Relating to or displaying atmospheric and weather conditions as they exist simultaneously over a broad area (IPCC, 2001).

Synoptic Air Mass Identification

Assessing the meteorological quality of the entire atmosphere; methods used to analyze relationships between total atmospheric conditions and the surface environment (McMichael et al., 2003).

System

An entity comprised of diverse but interrelated components that function as a complex whole. Examples include the climate system, ecosystems and market economies (Kump et al., 2004).

Threshold

The level of magnitude of a system process at which sudden or rapid change occurs. It is also a point or level at which new properties emerge in an ecological, economic or other system, invalidating predictions based on mathematical relationships that apply at lower levels (IPCC, 2007a).

Tools (for adaptation)

A generic term that refers to methodologies, guidelines and simplified processes that enable stakeholders to assess the implications of climate change impacts and relevant adaptation options in the context of their operating environment. Tools come in a variety of formats and have diverse applications: cross-cutting or multidisciplinary (e.g. climate models, scenario-building methods, stakeholder analysis, decision-support tools, decision-analytical tools) to specific sectoral applications (e.g. crop or vegetation models, methods for coastal zone vulnerability assessment) (Adapted from UNFCCC, n.d.)

Toxoplasma gondii

See toxoplasmosis.

Toxoplasmosis

A disease caused by the single-celled parasite *Toxoplasma gondii,* which is transmitted through ingestion of contaminated food or water, or through contact with cat feces. Most healthy individuals do not exhibit symptoms; however, pregnant women and individuals with compromised immune systems should exhibit caution (CDC, 2005b).

Traditional Knowledge

Various systems of knowledge, practice and belief gained through experience and culturally transmitted among members and generations of a community (ACIA, 2005).

Trichinella

See trichinosis.

Trichinosis

Also called trichinellosis. A disease caused by eating raw or undercooked meat of animals infected with the larvae of the roundworm *Trichinella.* Initial symptoms include nausea, diarrhea, vomiting, fatigue and fever. If infection is heavy, cardiovascular problems and, in severe cases, death may result (CDC, 2005b).

Troposphere

The lowest part of the atmosphere from the surface to about 10 km in altitude in mid-latitudes (ranging from 9 km in high latitudes to 16 km in the tropics on average) where clouds and weather phenomena occur. In the troposphere, temperatures generally decrease with height (IPCC, 2001).

Tropospheric Ozone

See ground-level ozone.

Tularemia

A zoonotic bacterial infection caused by the bacterium *Francisella tularensis,* generally found in animals such as rodents, rabbits and hares. Transmission occurs through ingestion of contaminated food or water, inhalation of the bacteria or from the bite of an infected insect. Symptoms include fever, chills, headache, diarrhea, and, depending on the route of exposure, ulcers on the skin or mouth, and swollen glands and eyes (CDC, 2005b).

Ultraviolet Radiation

Solar radiation within a certain wavelength, depending on the type of radiation (A, B or C). Ozone absorbs strongly in the UV-C range (<280 nm) and solar radiation in these wavelengths does not reach the Earth's surface. As the wavelength is increased through the UV-B range (280 nm to 315 nm) and into the UV-A range (315 nm to 400 nm) ozone absorption becomes weaker, until it is undetectable at about 340 nm (McMichael et al., 2003).

Uncertainty

An expression of the degree to which a value (e.g. the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a range of values calculated by various models) or by qualitative statements (e.g. reflecting the judgment of a team of experts) (IPCC, 2001).

United Nations Framework Convention on Climate Change (UNFCCC)

Convention signed at United Nations Conference on Environment and Development in 1992. Governments that become Parties to the Convention agree to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (WHO, 2003).

Urban Heat Island Effect

See heat island effect.

Urbanization

Net rural-to-urban migration, resulting in an increasing percentage of the population in any nation or region living in settlements that are defined as urban centres, and the associated conversion of land from a natural state or managed natural state (e.g. agriculture) to cities (IPCC, 2007a).

Vector

An organism, such as an insect, that transmits a pathogen from one host to another (IPCC, 2001).

Vector-Borne Disease

A disease that is transmitted between hosts by a vector organism such as a mosquito or tick (e.g. malaria, dengue fever, leishmaniasis) (IPCC, 2007a).

Vibrio parahaemolyticus

A bacterium in the same family as those that cause cholera. Causes gastrointestinal illness in humans, with symptoms including watery diarrhea, abdominal cramping, nausea, fever and chills. Infection is usually as a result of consumption of raw or undercooked shellfish, though the bacterium may infect open wounds (CDC, 2005b).

Voluntary Agency (Organization)

Organizations are considered to be part of the non-profit and voluntary sector if they are: organized (i.e. have some structure and are institutionalized to some extent, but not necessarily legally incorporated); non-governmental (i.e. are institutionally separate from governments); non-profit-distributing (i.e. do not return any profits generated to their owners and directors); self-governing (i.e. are independent and able to regulate their own activities); and voluntary (i.e. benefits to some degree from voluntary contributions of time or money) (Canadian Red Cross et al., n.d.).

Voluntary Sector

Includes both volunteers and those entities that are neither for-profit nor agencies of the state. It includes incorporated non-profit organizations as well as unincorporated volunteer community groups. It is also known as the community-based-sector, the non-profit sector, the third sector or the public benefit sector. The common feature is their reliance on volunteer boards of directors to govern their activities (Canadian Red Cross et al., n.d.).

Vulnerability

Vulnerability is susceptibility to harm. 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. Vulnerability to climate change is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2007a).

Water-Borne Illnesses

Water-borne illnesses result from exposure to pathogenic microorganisms or chemicals in drinking water or recreational water. Contaminated water most often enters the body by ingestion, but contaminants in water can also be inhaled, adsorbed or enter the body through contact with open sores or wounds (Environment Canada, 2001).

Water-Borne Diseases

See water-borne illnesses.

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 (Environment Canada, 2007).

West Nile Virus

A zoonotic virus transmitted by mosquitoes (normally *Culex*) and maintained in a wildlife cycle involving birds. Occasional spillover to the human population results after virus amplification and can cause large epidemics. Symptoms may be mild and include fever, headache and malaise, while symptoms of severe infection include high fever, neck stiffness, coma and paralysis (McMichael et al., 2003).

Wind Chill

The cooling sensation caused by the combined effect of temperature and wind. The wind chill poses a health hazard because it speeds up the rate at which a body loses heat (Environment Canada, 2002b).

Winter Road

A temporary roadway over frozen ground or a frozen body of water that facilitates transportation to and from communities and resource extraction sites without permanent roads (Manitoba Infrastructure and Transportation, n.d.).

Zoonosis

The transmission of a disease from an animal or non-human species to humans. The natural reservoir is a non-human animal (IPCC, 2001).

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