

Chapter 11

Public Health in Canada and Adaptation to Infectious Disease Risks of Climate Change: Are We Planning or Just Keeping Our Fingers Crossed?

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Abstract Climate change is expected to increase the health risks for Canadians from infectious diseases from our environment, including vector-borne, water-borne, and food-borne diseases. Adaptation efforts will be important to reduce the impact of these risks. Public health systems are in place in Canada to control many disease risks but there are still knowledge gaps on, and modifications needed to, existing approaches to protecting the population from endemic diseases and new or emerging pathogens. This chapter addresses five key questions on whether public health is on track to helping communities adapt to changing risks. The questions address adaptation to disease risk of climate change by exploring the following: assessments of disease risks, methods for adaptation, responsibility, resources, and public action and societal will. Overall, with these increasing risks to the health of Canadians, all sectors of society will need to participate in the adaptive response, while federal, provincial, and community public health bodies will need to work together to identify and communicate risk and promote and coordinate adaptation responses.

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Introduction

Climate change is expected to increase the health risks of Canadians from extreme weather events and infectious diseases found in nature. Studies in Canada and elsewhere highlight the potential impact of climate change on food-borne, water-borne, and vector-borne diseases, for which environment and climate are important determinants of risk. These determinants vary from increased temperature resulting in increased survival of pathogens through changes in the ecology and geographic range of disease reservoir and vector species. Adaptation to increased risks requires modification of existing approaches to protecting the population from familiar diseases and identification of new or emerging pathogens. Adaptation approaches will likely entail both dedicated interventions such as water treatment and vector control, and changes in human behavior to reduce risk of exposure.

This chapter addresses five key questions on whether public health is on track to help communities adapt to changing risks: (1) Have we made appropriate assessments of disease risks for developing adaptation methods? (2) What methods are available for adaptation to changing risks from food-borne, water-borne, and vector-borne diseases? (3) What levels of jurisdiction are responsible for adaptation? (4) What key resources are needed to establish effective adaptation? (5) Is adaptation dependent on public action and to what extent is it a product of societal will?

In addressing these questions, we discuss both general and specific methods of adaptation to food-borne, water-borne, and vector-borne disease risks. We conclude with a pragmatic look at the prospects for public health to respond to increased infectious disease risks due to climate change.

Have We Made Appropriate Assessments of Disease Risks for Developing Adaptation Methods?

There is concern that climate change will drive the emergence or reemergence of infectious diseases via various mechanisms (Table 11.1). These processes could be impacted by declining investment in control programs related to diseases previously controlled (Gubler and Wilson 2005). Food-borne, water-borne, and vector-borne diseases likely pose the most immediate increased risk to human health from altered climate conditions as they are linked to environmental and climate factors.

Prioritization of infectious disease risk must account for uncertainty about the quality of data available, the likelihood and extent of climate change effects, projected impacts in terms of pathogenicity, projected numbers of cases, and the potential costs and benefits of adaptation approaches (Watson et al. 2005).

Table 11.1 Mechanisms of emergence of infectious diseases and suggested links to climate change

Mechanism	Example	Direct effect of climate change	Indirect effect of climate change	Possible evidence for climate change effects to date
1. Emerging ability to recognize or diagnose an infectious disease	All emerging infectious diseases	No	No	-
2. Emergence due to range expansion of endemic areas	Lyme disease and raccoon rabies in Canada; Bluetongue virus in the Mediterranean	Changed geographic footprint of suitable temperature/humidity for vector survival and bacterial or viral multiplication	Increased habitat suitability or reservoir host abundance	Bluetongue virus in the Mediterranean (Purse et al. 2005); Lyme disease in Canada (Ogden et al. 2008a); malaria in Kenya (Pascual et al. 2006)
3. Emergence due to accidental introduction	West Nile virus in North America; SARS in Canada; airport malaria worldwide	Enhanced survival of introduced vectors and pathogens	Increased abundance of vectors and pathogens in endemic areas; increased or changed human movements and migrations	No
4. Emergence due to evolution of new pathogenic microorganisms	Highly pathogenic avian influenza	No	Effects on ecological dynamics affecting fitness of different genetic variants	No
5. Reemergence of endemic disease and, for zoonoses, "spill-over" from animal to human hosts	Food-borne and water-borne diseases; hantavirus in Western United States; <i>E. coli</i> O157 in Canada	Increased temperatures affecting pathogen multiplication; heavy rainfall enhancing human-pathogen contact	Enhanced abundance of pathogens in the environment via effects on ecological dynamics	No

Studies in Canada have explored relationships between disease or vector occurrence and climate variables through qualitative assessments and simple statistical or mathematical models. These are then applied to climate scenarios to attempt to quantify possible effects of climate change on disease occurrence (Ontario Forest Research 2003; Fleury et al. 2006; Thomas et al. 2006; Ogden et al. 2005, 2006). There is considerable knowledge of drivers of endemic diseases and this knowledge may be sufficient to allow adaptation to changing degrees of risk. The relation between ecosystems, infectious diseases, and global climate change are less intuitive in developed countries where water treatment, vector control, and higher quality housing partly mitigate infectious disease threats (Greer et al. 2008). However, to be sure, we need further analyses on the complex interactions of climate (and extreme weather events) on microbial or vector replication and survival, the natural environment, and on the human–environmental interaction, which includes human population growth and movement, habitat disruption, and modification.

The need for broader assessment of climate change on infectious diseases is illustrated by recent assessments of how climate change may affect transmission of vector-borne diseases. Vector-borne diseases are transmitted by arthropods (ticks and flies), from human to human (often by mosquitoes, e.g., malaria, dengue), or from animal reservoirs (mostly wildlife) to humans (vector-borne zoonoses). The latter are transmitted by a variety of arthropod species: West Nile virus is transmitted from birds to humans by mosquitoes, Lyme disease is transmitted from rodents to humans by ticks, and Bartonellosis is transmitted from rodents by fleas.

There is a global debate about the extent to which climate change may affect vector-borne disease ecology and disease risk. The debate has centered on key human-to-human transmitted vector-borne diseases such as malaria and dengue, and this debate has significance for how seriously threats of vector-borne diseases are considered in developed countries such as Canada. The two opposing points of view are reviewed in Box 11.1.

Box 11.1 Vector-Borne Diseases and Climate Change: The Debate

1. Climate change will have a large impact on global vector-borne disease risks:

Strengths: Inherent, known, links between vector biology and climate (such as temperature influences on the “extrinsic incubation period”: Rogers and Randolph 2006) mean that cautious risk assessments may be advisable (Martens et al. 1995; Patz et al. 1998). *Weaknesses:* Assessments have been based on simplified mathematical models that are likely very inaccurate (by overestimation) at identifying where vector-borne disease risk occurs (Rogers and Randolph 2006). Simplified models ignore climate-independent determinants of risk including habitat, biodiversity, and factors unrelated to the environment such as resistance to antimalaria

drugs and societal wealth and health (Reiter 2001; Reiter et al. 2004; Charron et al. 2008).

2. Climate change will have a small impact on global vector-borne disease risks:

Strengths: Assessments are based on statistical models that associate current known vector-borne disease occurrence with climate, and sometimes habitat variables, to identify current and future environmental footprints for vector-borne diseases (Rogers and Randolph 2000, 2006).

Weaknesses: Observed statistical observations do not necessarily imply causality, and the statistical models have attempted to identify an “ecological niche” when the distribution of human-to-human transmitted vector-borne diseases is likely partly determined by societal factors not currently investigated in statistical models (Berrang-Ford et al. 2009).

Of significance to the debate is that: (1) we have limited information on the real effects of climate, relative to other factors, on the biology of vectors and vector-borne disease, except in a few examples such as Lyme disease (Ogden et al. 2004, 2005, 2006), and on which to base quantitative assessments of climate change impacts on vector occurrence and vector-borne disease incidence; (2) efforts to synthesize existing data on vector and vector-borne disease occurrence and ecology have been limited to date; and (3) with the exception of Bluetongue virus (Purse et al. 2005), perhaps malaria in a focal region (Pascual et al. 2006), and Lyme disease vectors in southeastern Canada (Ogden et al. 2008a), our recent and current efforts to attribute climate and climate change effects, or effects of alternative factors, rest on imperfect data. Thus, we have limited ability to determine climate effects on vector-borne disease occurrence and to predict and identify any climate change effects. It would be expected, however, that estimation of climatic influences and prediction of climate change effects on vector-borne zoonoses would be more robust than for diseases maintained in a human–vector–human transmission cycle, as the former are relatively independent of the occurrence of human cases.

Similarly, it remains difficult to assess the true burden of illness from enteric pathogens. We have started addressing the impact of climate change on food-borne and water-borne diseases in Canada by linking precipitation and temperature to enteric diseases and water-borne disease outbreaks (Charron et al. 2004; Fleury et al. 2006; Thomas et al. 2006). However, transmission routes include person to person, water, food, and the environment. Understanding these dynamics is difficult because investigation of the source of individual cases is not routine (Mead et al. 1999) and enteric symptoms may relate to non-enteric causes (Powell et al. 2007). Systems to ensure food safety, from the farm, through processing, to retail and consumption are established in Canada. Since the Walkerton outbreak, where excess rainfall resulted

in contamination of the water supply, there have been advances in water safety regulation and water quality monitoring in Canada (Auld et al. 2004).

There are, however, key knowledge gaps on: (1) the ecology and epidemiology of vector-borne, food-borne, and water-borne diseases; (2) understanding of how human social and societal factors interact with the ecology of these diseases; and (3) synthesis of existing information on disease ecology, epidemiology, and societal factors that convert potential risks into real risks for public health, and investigations on how climate change may indirectly affect these risks via effects on socioeconomic conditions. These gaps hamper precise quantified risk assessments and we argue that, at present, we must use available risk assessment methods to identify potential risks, but interpret the assessments using the precautionary principle.

What Methods Are Available for Adaptation to Changing Risks from Food-Borne and Vector-Borne Diseases?

To meet the public health challenge of climate-change-induced changes to the distribution and frequency of endemic diseases, emergence of new diseases, and importation of diseases and disease vectors into Canada, a coordinated response of public health and environmental health infrastructures will be essential. Four key elements to response are presented in Box 11.2.

Box 11.2 Elements of Response

The key elements to this response involve:

1. Disease surveillance capable of detecting the geographic and temporal occurrence of emerging and reemerging diseases
2. Surveillance data analysis and communication
3. Networking amongst public health jurisdictions
4. Effective interventions to prevent disease or reduce incidence

Timely detection of disease events implies a surveillance infrastructure capable of identifying both routine and unusual events via regular data analysis. Surveillance programs in Canada are comprehensive for common food-borne and water-borne diseases and some vector-borne zoonoses. They include: direct reporting of laboratory confirmed infections at the local and provincial levels; national, provincial, and territorial reporting of notifiable diseases and selected laboratory identifications of enteric pathogens; as well as provision of laboratory reference services both provincially and nationally. In some cases, nontraditional indicators of health and innovative approaches may be used in disease detection programs. For example,

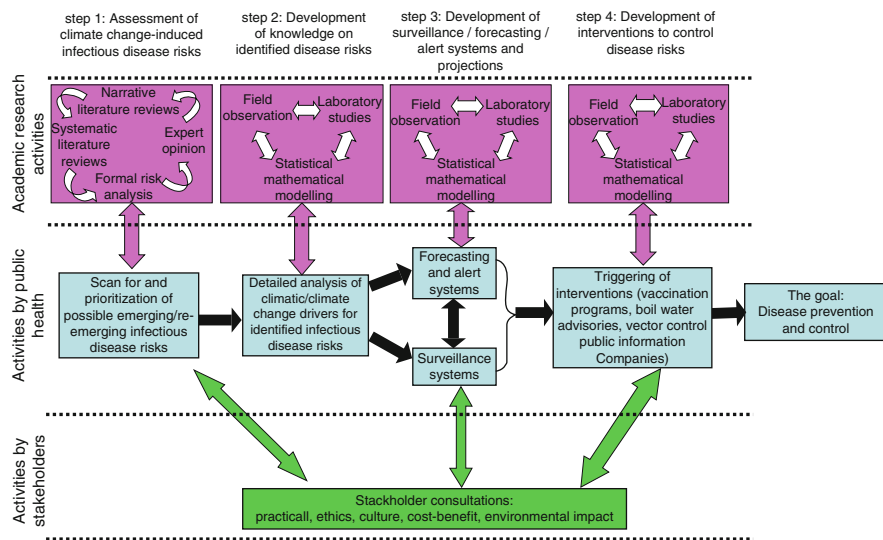


Fig. 11.1 A flow chart of adaptation activities required to identify and respond to emerging infectious disease threats driven by climate change. *Arrows* indicate the flow of adaptation activities from initial identification of climate-change-driven disease risks through knowledge acquisition and development of surveillance, forecasting or alert systems and the interventions they trigger to prevent or control disease, as well as collaborations with science research institutions and stakeholders

pharmacy data on over-the-counter sales, emergency room visits, and Telehealth calls can provide early warning for local disease events (Edge et al. 2004; Edge et al. 2006). “Environmental” surveillance to detect infection in sentinel animals or vectors and forecasting (Teklehaimanot et al. 2004; Bouden et al. 2008) to detect disease risks before they occur in humans will be crucial to minimizing risks from emerging zoonoses. Canada has relatively comprehensive programs for monitoring trends in food-borne and water-borne diseases and some vector-borne zoonoses. However, as in other developed countries, many diseases are underreported and national statistics represent trends in disease patterns rather than incidence or prevalence of disease (Flint et al. 2005; Majowicz et al. 2005). While current surveillance approaches in Canada successfully report trends for common diseases, these programs may be less effective for monitoring rarer events, new diseases, and diseases not captured in national statistics.

Methods to detect new or unusual diseases should be based on detailed comprehension of pathogen ecology and yield defensible threshold values for risk which trigger interventions. Ideally, feedback in the system will incorporate analysis of surveillance data and comparison with forecasts/projections, and evaluation of the efficacy of interventions. This “ideal” system is summarized in Fig. 11.1. Current initiatives in Canada, such as the C-EnterNet pilot study in Waterloo, Ontario, integrate current information on human enteric disease with levels of pathogen

exposure from food, animal, and water sources to detect changes in trends and to contribute to the risk management process (Public Health Agency of Canada 2007).

Sharing data and information within networks and between jurisdictions facilitates risk identification and contributes to defining the scope and spread of risk. The public health response to West Nile virus in Canada provides an example of how networking of surveillance information is feasible in large countries with multiple jurisdictions and mandates. Although the technology exists for rapid information sharing, privacy and confidentiality requirements challenge surveillance objectives. The range of diseases that climate change may affect suggests that these issues must be addressed through planning of data information systems and by identifying the needs and information required for timely data sharing. Timely analysis of surveillance data to identify where and when disease risks are occurring and presentation of these analyses in a way meaningful for public health professionals are essential to effective disease control. Thus, capacity in surveillance, epidemiology, risk modeling, geographic information systems (GIS), and communications will be important to adaptation.

Interventions to prevent or limit many predictable disease risks in Canada include: water treatment, food safety through hazard control, and vector-borne disease control programs. Regulation of imported foods, animals, and animal products also limits the potential for the introduction and establishment of animal diseases. Regulations and guidelines are relatively easily adapted to changing disease risks but imply an established infrastructure to monitor their effectiveness and to respond when issues arise. Canada's regulatory requirements are designed to protect human and animal health interests within an international travel and trading environment. This includes the import–export requirements of trading partners and international obligations of reporting and control of diseases under the World Health Organization (WHO) International Health Regulations and the World Trade Organization (WTO) Sanitary and Phytosanitary (SPS) Measures (WHO 2005).

Some risks may require development of new interventions. For example, capacity to respond effectively to tick-borne zoonoses is limited and under development (Piesman and Eisen 2008). For emerging diseases, information for medical professionals and the public will be important in reducing human exposure and ensuring rapid diagnosis and treatment (Public Health Agency of Canada 2005; Ogden et al. 2008b). Furthermore, Canada's experience with West Nile virus emphasized the need for increased availability of expertise in entomology and vector-borne disease control and demonstrated the need to develop capacity in public health. For water-borne diseases there is a need to enhance watershed management, and update water treatment facilities and sewer systems built to cope with past rainfall projections that may not have enough capacity for future extreme weather events linked to climate change.

What Levels of Jurisdiction Are Responsible for Adaptation?

In Canada, national standards and policy and regulatory frameworks focus on supporting safe food supplies, preventing the importation of contaminated foods, and maintaining the health of economically important animals. Enforcement and implementation of much of these regulations are delivered by the provincial, territorial, and municipal levels. Changes in public health risks resulting from climate change will therefore impact multiple levels in Canada's political infrastructure. However, climate impacts will vary across the country and some effects may be relatively local. For these reasons, the municipality is likely to play a major role in adaptation alongside provincial or territorial and national authorities (Ebi and Semenza 2008). This implies that local health authorities recognize the issue and make adaptation to changing disease risks a priority. At the provincial and municipal levels, these responsibilities can be addressed by multiple sectors such as agriculture, health, sustainable development, and natural resources. At the national level, the organizations likely to play a major role in adaptation include federal departments and agencies with responsibilities for agriculture and food, environment, and public health. The Canadian response to West Nile virus offers an interesting model in which initial federal government leadership to address the incursion of this new infectious disease in North America has devolved to provincial and municipal decision-making surveillance, and prevention and control activities. This approach permits local needs and concerns to be addressed, including the acceptability of some measures (see Box 11.3).

Box 11.3 Case Study of West Nile Virus

The arrival of West Nile virus in North America in 1999 and the subsequent spread of the virus west across the continent provided a model for future adaptation to an emerging infectious disease. The federal government response was coordinated across three departments, which linked surveillance, blood safety, and communications activities both horizontally across departments and vertically with provinces and territories and also linked internationally with the United States and the WHO. A national multi-jurisdictional collaboration was developed to monitor for dead corvids and mosquitoes infected with West Nile virus. The monitoring program itself was managed by a wildlife health NGO, the Canadian Cooperative Wildlife Health Centre, which in turn coordinated diagnostic and surveillance activities within Canada's veterinary colleges. In the absence of a human vaccine, communications advice on limiting exposure to infected mosquitoes continues to be a major component of the control and prevention activity. Information on virus activity has played a major role in local decision-making about mosquito control and targeting of health protection advice, and over time much of the monitoring and control activity has devolved to the provincial and municipal levels.

In responding to the impacts of climate change, the importance of nongovernmental organizations (NGOs) should not be underestimated. Whilst these organizations have no mandate to develop policy and implement regulations, they play important roles. For example, university research programs provide information essential to understanding the science related to climate change. National professional bodies such as the Canadian Public Health Association help develop public health and research priorities, can improve both professional and public awareness of issues, and provide an independent scientific opinion to decision-makers. The Canadian Red Cross plays a major role in responding to severe events and disasters. Industry-based associations promote response to climate-linked issues through improving awareness, development of industry-based guidelines and codes of practice. Finally, public advocacy groups play a role in identifying issues and scrutinizing industry and government response to problems.

What Key Resources Are Needed to Establish Effective Adaptation?

Climate change has major implications for the awareness, preparedness, analysis, and action responsibilities of public health. Awareness requires a clear understanding of the risks, while preparedness, analysis, and action mean development of a surveillance and response strategy that addresses the anticipated evolving risk from infectious diseases with a sustainable long-term program (Frumkin and McMichael 2008). These require public buy-in to actions that may impact personal lifestyle at one extreme, to future municipal and provincial resource allocation and planning at the other. Communication with the public and across organizational boundaries of both risks and consumer incentives to address them will be essential in obtaining support for development of cross-sector adaptive strategies (Semenza et al. 2008).

Public health preparedness has two components: ability to assess immediate and evolving risk to communities and populations and the ability to respond to emergency events. In the context of climate change, this includes changes that will occur over decades as well as sudden disaster or near disaster events. Canada is relatively well prepared for disaster scenarios with organized multilevel public health and disaster response infrastructure and planning. However, Canada is just beginning to address the longer term implications of climate change in health, including infectious diseases. Action to date has focused on reporting the implications of climate change and investment in developing approaches to adaptation (Charron et al. 2008). However, municipalities need to be prepared for projected future climate change effects (on an unprecedentedly long timescale) that integrate other pressures on infrastructure, such as population expansion and demand for potable water that is protected from contamination in the most environmentally sustainable way.

Key to development of adaptive approaches will be the ability to predict and detect current, emerging, or new health events. These requirements are predicated

on the ability to access appropriate data and information and to apply appropriate analysis to provide clear understanding of the current incidence or prevalence of a disease and to model future trends.

Public health action to address infectious disease risk has four important requirements. First is the effective and balanced communication of climate change-related health issues, which identifies the type of risk, its likelihood to occur, the time period over which it may occur, and the alternative actions of the individual or society which may be needed to reduce risk.

Second is to promote the value and strength of public health and population health approaches to identifying and addressing risks. By addressing such risks, the whole population benefits from broadly applied risk reduction strategies. Some interventions, such as the application of population-wide vaccine programs to prevent or control infectious diseases have been in place now for several decades. The effectiveness of such strategies is amply demonstrated by temporal reductions in such diseases as measles, rubella, diphtheria, and pertussis.

Third is the utilization of accurate and timely information to inform public health policy. As with specific public health interventions such as vaccination programs, Canada has a long history of policy activity designed to protect individuals and populations from harm. This can be an adaptive process that recognizes new expectations and the ability to respond to new threats. For new and emerging diseases, challenges related to food supply globalization and rapid travel to exotic locations require policy and regulation capable of responding to new risks while at the same time accommodating economic realities.

Last, the promotion of multidisciplinary and collegial approaches to the analysis of data and information from multiple sources, and the assessment and analysis of risk will facilitate development of policy and action. This component depends on the availability of essential and appropriate data, opportunity and willingness to share data and information, to form strategic research alliances, and to develop innovative use of forecasting, surveillance, and intervention.

These responses are predicated on the availability of appropriate resources and leadership, and where the responsibilities for these lie remains to be decided. Clearly, essential resources extend beyond purely financial components to include technologies, infrastructure, expertise, research, multi-sectoral collaboration, and corporate and individual responsibility.

Is Adaptation Dependent on Public Action and to What Extent Is It a Product of Societal Will?

The most recent report of the Intergovernmental Panel on Climate Change (IPCC) confirms that health impacts linked to climate change are being detected worldwide and that some regions and populations (e.g., the young, elderly, aboriginal populations, and those living in polar and coastal regions) will experience greater

impacts (IPCC 2007, p. 104). In general, public health professionals recognize the importance of developing adaptive capacity and approaches to adaptation now, but investment in public health preparedness for climate change-related risks will depend on public and societal support. Thus, the ultimate test of awareness of the impacts of climate change and their challenge to health may be a societal response that demands effective public health action. We suggest four requirements for support for public health action on climate change in Box 11.4.

Box 11.4 Four Requirements for Support for Public Health Action on Climate Change

1. Promotion of the values and strengths of population-based approaches to surveillance and interventions to preserve and improve health through concerted societal action. The public health and communicable diseases arena has a strong history of adaptation to infectious disease risk, and a multi-sectoral armament of responses involving individual and population-based action.
2. A multi-sectoral, multidisciplinary, collegial approach to analysis, assessment, and response to complex public health threats.
3. Public health policy and communications that are informed and directed by the best available scientific evidence.
4. Effective communications on climate change-related health issues that are scaled according to the audience, whether health professionals, the public, vulnerable groups, etc., and should provide culturally appropriate, transparent, and balanced information about health risk. The potential for communication approaches to promote changes in behavior at the individual and population levels should not be underestimated (Maibach et al. 2008).

The key elements of a societal approach to adaptation include: consideration of the need for accurate assessment of potential threats; recognition of the timelines over which health threats will occur; the social and economic costs and benefits of doing something, or nothing; and consideration of the societal impacts of adaptation (Roberts 2006; Stern 2007). Stern (2007) makes three key points about adaptation that are crucial to understanding an adaptation framework: (1) adaptation is essentially unavoidable, (2) adaptation cannot solve the impacts of climate change but will contribute to limiting those impacts, and (3) the benefits of adaptation will be largely local and can have relatively rapid results.

This chapter has sought to clarify some of the issues posed by the current and future predicted impacts of climate change on infectious disease risks, particularly food-borne, water-borne, and vector-borne agents. Addressing these risks through

adaptation approaches is a broad objective of public health which will engage all levels of government, research, industry, and the public in making choices. Government response will inevitably promote a horizontal approach incorporating issues of trade, travel, and animal health in assessing human health and economic risks. Not all choices will be financially costly but may require individual lifestyle changes, such as regular use of insect repellent or education of doctors to include emerging diseases such as Lyme disease in their differential diagnoses. Other strategies would be more expensive with benefits realized over decades, as in the case of safe drinking water infrastructure investment. In the longer term reduced vulnerability to climate change effects, including altered risks to infectious diseases, may have more to do with improved “social and material conditions of life,” and leveling of “inequalities within and between populations” at risk (McMichael and Kovats 2000). What is clear is that all sectors of society will be involved in the response and that government has a leadership role in identifying and communicating risk and promoting and coordinating, and sometimes funding, response.

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