Public health

Climate change and infectious diseases in North America: the road ahead

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ABSTRACT

Global climate change is inevitable — the combustion of fossil fuels has resulted in a buildup of greenhouse gases within the atmosphere, causing unprecedented changes to the earth's climate. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change suggests that North America will experience marked changes in weather patterns in coming decades, including warmer temperatures and increased rainfall, summertime droughts and extreme weather events (e.g., tornadoes and hurricanes). Although these events may have direct consequences for health (e.g., injuries and displacement of populations due to thermal stress), they are also likely to cause important changes in the incidence and distribution of infectious diseases, including vector-borne and zoonotic diseases, water- and food-borne diseases and diseases with environmental reservoirs (e.g., endemic fungal diseases). Changes in weather patterns and ecosystems, and health consequences of climate change will probably be most severe in far northern regions (e.g., the Arctic). We provide an overview of the expected nature and direction of such changes, which pose current and future challenges to health care providers and public health agencies.

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Human activities have caused a sharp increase in greenhouse gases, including carbon dioxide, nitrous oxide and methane, in the atmosphere, which has led to unprecedented changes in the earth's climate. The Intergovernmental Panel on Climate Change was established by the United Nations Environment Program and the World Meteorological Organization in 1988 to provide objective analysis of data related to climate change. The panel comprises scientists from around the globe and aims to present the scientific, technical and socioeconomic issues arising from the data to government decision-makers in a policy-neutral context.

In April 2007, the panel issued a report on the impact of global climate change on human and animal populations.[1] This report was based on about 30 000 observations of changes in physical and biological systems worldwide. More than 90% of these changes are attributable to human activities such as the combustion of fossil fuels.[1,2] The panel's fourth assessment report includes projections for regions including North America. These projections include warmer temperatures (Figure 1), more rainfall because of an increased fraction of precipitation falling as rain rather than snow, and more frequent droughts, wildfires and extreme weather events such as hurricanes and tornados.[1] Warming is predicted to be most severe in the northernmost latitudes.

Some of the health effects attributable to climate change are directly related to changing environmental conditions. The Public Health Agency of Canada anticipates increased burden of disease as a result of thermal stress and more frequent extreme weather events,[3] and some projected direct effects of climate change on human health, such as heat-related morbidity and injuries, have been previously reviewed.[4] However, climate and weather patterns are important physical components of complex ecosystems[5] and any major change in the nonliving component of an ecosystem will affect living components, including microbes, insect vectors, animal reservoirs and susceptible humans, and change the incidence and distribution of infectious diseases.

The close relation between climate, environment and infectious disease in the developing world are well recognized. For example, the importance of rainfall and drought in the occurrence of malaria,[6,7] the influence of the dry season on epidemic meningococcal disease in the sub-Saharan African "meningitis belt"[8] and the importance of warm ocean waters in driving cholera occurrence in the Ganges River delta and elsewhere in Asia[9] are well described. Indeed, there is widespread concern about the potential impact of global climate change on the distribution and burden of these and other infectious threats in the developing world.[1,7]

The relation between ecosystems, infectious diseases and global climate change are less intuitive in the context of more developed countries where clean drinking water, reduced exposure to insect vectors, higher-quality housing and other advantages partly mitigate such threats. However, cli-

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Key points of the article

- Global climate change is occurring as a result of greenhouse gases created by human activities. Changes in climate and associated changes in weather and other environmental exposures will have important consequences for human health.
- Climate change will alter the relations between microbes, insect vectors, animal reservoirs of infectious diseases and humans, and will alter the burden and distribution of infectious diseases of public health importance.
- Warmer temperatures and altered rainfall patterns are likely to increase the range and burden of vector-borne infectious diseases in North America and elsewhere.
- Altered patterns of rainfall and increased frequency of extreme weather events are likely to influence the incidence of water-borne gastrointestinal and respiratory diseases in North America and elsewhere.
- The best defence against increases in infectious disease burden related to climate change lies in strengthening existing public health infrastructure. Physicians, as opinion leaders, can also influence public policy related to greenhouse gas emissions.

mate changes projected to occur in the coming decades are likely to influence the burden and incidence of infectious diseases in more developed regions including North America. In this review, we describe the nature and direction of changes in infectious disease epidemiology that are likely to accompany global climate change and describe the challenges that these changes will pose to health care providers and public health agencies. We focus principally on Canada and the United States, including the Arctic regions of North America, where the effects of global climate change are likely to be most severe. We also include several illustrative examples from other highly developed regions such as the European Union and Australia. In particular, we review several zoonotic diseases of public health importance, the association between precipitation and water-borne diarrheal diseases, seasonal respiratory diseases with person-to-person transmission and endemic mycoses (Table 1).

This review is not meant to obscure the likelihood that the brunt of the increased incidence of infectious diseases related to climate change will occur in the same less-developed, economically poor countries that are currently most affected by infectious diseases.[1,10] For more information about the projected changes in infectious disease epidemiology in these diverse regions of the world, we encourage readers to consult the panel report and other reports and reviews devoted to this topic.[1,7,11,12]

Zoonotic and vector-borne diseases

Climate change may affect zoonoses (infectious diseases of animal origin that may be transmitted to humans) in 3 ways: it may increase the range or abundance of animal reservoirs or insect vectors, prolong transmission cycles, or increase the importation of vectors or animal reservoirs (e.g., by boat or air) to new regions, which may cause the establishment of diseases in those regions. For example, the burden of Lyme disease (a tick-borne borreliosis) is likely to change substantially in North America and Europe. Currently, endemic Lyme disease is uncommon in Canada, and established populations of competent vectors (vectors that are capable of allowing the pathogen to complete its lifecycle, such as *Ixodes scapularis* and *Ixodes pacificus*) are limited largely to southern Ontario, Nova Scotia and British Columbia.[13] However, temperature determines the northernmost extent of tick populations. Mathematical models suggest that tick abundance may greatly increase in southern Canada, with a northern expansion of about 200 km by the year 2020. This rate of expansion would be sufficient to establish vector populations in Alberta and Saskatchewan (Figure 2).[13]

In North America, other infectious diseases that may expand their ranges because of northern expansion of vector populations include such tick-borne threats as babesiosis, anaplasmoses and Powassan encephalitis in addition to mosquito-borne threats such as dengue. In Europe, the expansion of the range of ticks and other vectors (e.g., sandflies) may increase the incidence and distribution of Lyme disease,[14] boutonneuse fever[15] and leishmaniasis.[16] In Aus-

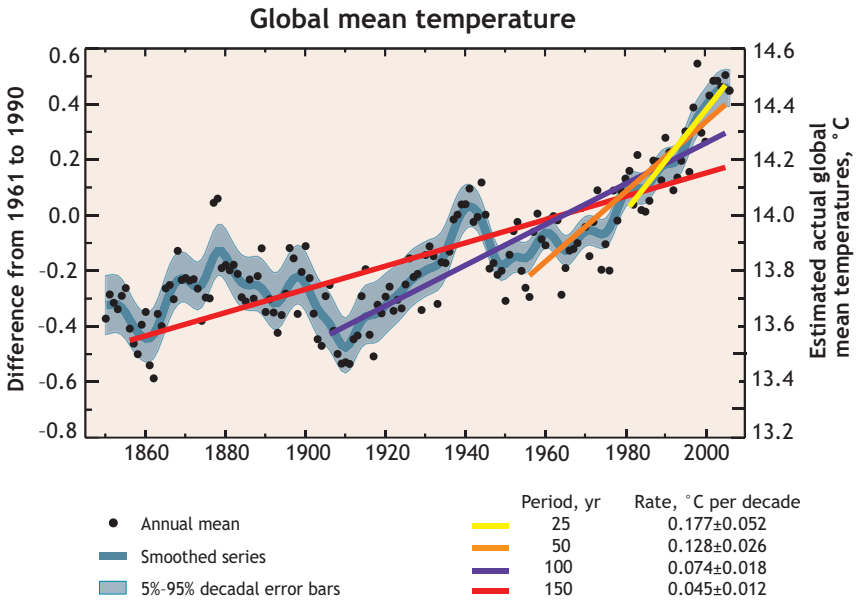

Figure 1: Trends in mean global temperatures since the mid-19th century. Coloured lines represent the linear trends over various time periods. Shorter (more recent time periods) lines have steeper slopes, indicating an accelerating warming trend for the planet. Reproduced, with permission, from reference 2. Copyright 2007 Cambridge University Press.