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Climate Change and Health in British Columbia

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EXECUTIVE SUMMARY

The purpose of this paper is to outline how climate change is likely to affect the health of British Columbians and to suggest a way forward to promote health and policy research, and adaptation to these changes.

- BC's climate has warmed, rainfall has increased and more extreme weather events are now occurring.
- Climate change will act on the health of British Columbians directly through physical and biological pathways and, indirectly through complex socio-economic and environmental pathways.
- The direct physical and biological pathways will be the easiest to investigate, monitor, and attribute to climate change.
- The indirect socio-economic pathways will have the greatest impact, be the most complex to investigate and monitor, and be the most difficult to attribute to climate change.
- These indirect impacts on health will be most severe in communities that already face significant environmental and socio-economic adversity.
- At present, rural and remote forestry-dependent and Aboriginal communities in mountain pine beetle infected zones are particularly vulnerable because they are already buffeted by more adverse environmental and socio-economic circumstances than more diversified communities.
- There is a double de-stabilization threat to rural and remote resource-dependent and Aboriginal communities because some will also be exposed to increased frequency of fires and floods (because forests infested with MPB are at heightened risk for fire and flood) which will have dramatic and direct effects on health.
- *It is essential that research on human health effects of climate change must, not only grapple with the intensity and pace of climate change but also with the location and extent of vulnerability of human populations most likely exposed to climate change.*
- While there is strong evidence for shifts in climate in BC, *there is virtually no direct evidence yet available on the impact of climate change on human health in BC.*
- There is therefore a need for a substantial "made in BC" climate change and health research program. While waiting for the results of this program of research, the precautionary principle demands that immediate action be taken to develop the policy and infrastructure required to promote adaptation to climate change.

We suggest the following five main principles to guide development of research and policy to better predict future impacts of climate change on health and to enhance adaptation to these change in BC.

1. *Basic research is required to develop "made in BC" models and infrastructure for climate change and health investigations.*

Including: 1) better local meteorological data, 2) downscaled climate datasets, 3) models that apply accurate regional climate change predictions to regional topography, hydrology and ecological systems, to accurately predict flood and fire risk etc., 4) research elucidating pathways between climate change and diseases that are common in BC, 5) high quality longitudinal health data sets for research building on the BC Linked Health Database.

2. *Climate change will aggravate existing health disparities in BC so that research and adaptive policy must, in the immediate future, be focused on rural and remote resource-dependent communities, particularly those directly affected by the mountain pine beetle infestation and in remote Aboriginal communities as well as in vulnerable urban neighborhoods. Risk perception and social capital research is fundamental to better understanding future health impacts and the best ways to develop adaptive policies now.*

3. Development of adaptation policy requires education and mobilization of the public as well as health and other professionals. Better understanding of the risk of climate change to health among the general public and policy makers is essential.

4. *Adaptation to climate change will require development of new collaborations across government, regional health authorities, and non-government agencies as well as an enhanced leadership role for public health authorities.*

5. *Climate change will strain the provincial health service in uneven fashion across regions. To ensure equitable access to health services better understanding of the future impacts of climate change on health services is required.*

1.0 INTRODUCTION

Much of the research on health in relation to climate change is based upon the impact of major weather driven disasters on health and on the exposure of human populations to extreme temperatures, mainly heat. Many of these, and other climate health research investigations, have been conducted in developing nations. There is a dearth of studies based in BC or in places in developed nations with similar climates and environments. As well, research frameworks describing the complex, indirect, linkage between climate change and the main diseases of concern in a place like BC (i.e., cardio-vascular, cancer, diabetes, mental health etc.) have not been well articulated.

Disentangling the complex indirect pathways between climate change and health is a challenging research endeavour that requires the development of new inter-disciplinary academic partnerships and cross-industry, governmental, and professional alliances as well as the development of a research infrastructure to provide more accurate data on the future impacts of climate change on human health in BC. Given the complex way in which climate change will act in concert with other socio-economic and environmental factors it is best to approach the study of climate change and health using a social determinants of health framework.

The World Health Organization has encouraged public health officials to act now even in the face of scientific uncertainty (McMichael et al., 2003). Successful adaptation by communities has the potential to reduce the burden of climate change on specific adverse health outcomes.

The purpose of this paper is to outline how climate change is likely to affect the health of British Columbians and to suggest a way forward to promote health, policy research, and adaptation to these changes. Given that climate change is well underway, that we need adaptive strategies to reduce current and future health impacts and, given the relevance of the precautionary principle in this situation, it is essential to both develop a coherent provincial approach to climate change and health research and adaptation based on what we know about the links between climate change and health at present, and to immediately build the research infrastructure to better predict future impacts on health of climate change.

In the first section of this paper, we describe the climate changes likely to occur in BC. In the second section, we outline the evidence linking climate change to adverse health outcomes. Because there is limited evidence available for BC, we extrapolate this to suggest possible impacts of climate change on the health of British Columbians. In the third section, we outline a "made in BC" set of principles and priorities for a research and policy agenda to improve adaptation to the health impacts of climate change.

2.0 CLIMATE CHANGE IN BC

BC's climate has warmed significantly in recent decades with changes in temperature and precipitation exceeding global averages in southern BC (BC Ministry of Environment, 2006; Whitfield et al., 2002a; Zhang et al., 2000). Conditions will likely become wetter in most regions of the province during the winter and spring and drier during summer, at least in the south and on the coast (Walker and Sydneysmith, 2007).

As well, more extreme weather events are now documented worldwide with most projections suggesting these are on the increase (Easterling et al., 2000). In the period 1999 to 2002, extreme climate-related natural disasters cost BC an average of 10 million dollars per year. In the period from 2003 to 2005 average yearly costs of these types of disasters rose to 86 million dollars per year indicating a dramatic recent increase in the impact of extreme weather events in BC (Whyte, 2006)

In BC, large temperature increases have resulted in reduced snowpack (Stewart et al., 2004). Reductions in snowpack have changed streamflow volumes and timing. In particular, spring snowmelt now occurs much earlier in many BC rivers (Zhang et al., 2001) and alpine glaciers are melting rapidly (Moore et al., 2007). Increasing temperatures and precipitation will reduce snowpacks in the future, thus increasing winter runoff for most of BC (Mote and Hamlet, 2001). Groundwater recharge rates are also sensitive to changing climate conditions (Rivera et al., 2004). These factors, in combination with higher evapotranspiration, mean that there will be reduced summer-time flows in many BC rivers, a particular issue for the Okanagan region and, in terms of sectors, for energy and agriculture.

Sea level rise will be a hazard for coastal communities in BC. However, accurate predictions about the impacts of sea level rise are difficult to make (Walker and Sydneysmith, 2007). Nonetheless, sea levels will rise in the future in BC posing challenges, particularly in southwestern BC with its concentration of urban population and infrastructure. Sea level rise may also cause groundwater quality degradation in coastal communities that rely on groundwater.

3.0 WHAT ARE THE LONG TERM HEALTH EFFECTS OF CLIMATE CHANGE IN BRITISH COLUMBIA?

In order to assess what these effects might be in the future, it is first necessary to briefly describe the models that scientists use to investigate the links between climate change and health. We then review the evidence for possible impacts of climate change on human health.

3.1 Framing studies of climate change and health

Several conceptual models have been developed in order to frame research on the impacts of climate change on health (McMichael et al., 2003). Most of these focus on the health impacts of climate change in developing nations as they tend to have large populations already suffering from ill health, few resources to adapt to either the direct impacts of severe weather events or their indirect long term sequelae, and little institutional capacity to drive adaptation to climate change (Adger et al., 2003; Kristie et al., 2006; Lieshout et al., 2004).

Climate change is conceptualized, in most of these models, as impacting human health directly or indirectly (Haines et al., 2006a, 2006 b). Direct effects might be death and illness due to thermal extremes arising from severe heat waves (Campbell-Lendrum and Corvalan, 2007) or from the direct effects of flooding (Ahern et al., 2005). Most climate change research has been conducted on the direct effects of climate on health. Since 1970, the WHO conservatively estimates 150,000 deaths per annum from such effects (Adger et al., 2003; Campbell-Lendrum and Corvalan, 2007; Kristie et al., 2006; Lieshout et al., 2004). These events have significant immediate public health impacts (e.g., excess deaths from the European heat-wave

in 2003) (Robine, 2007) and, from a research and policy standpoint, offer the potential to demonstrate a direct link with climate change.

Indirect effects on health arise from the sustained impact of altered climate, which causes changes to ecosystems and which, in turn, impacts human health through various pathways (Martens, 1998). For example, rises in temperature may alter living conditions for animal and plant vectors of diseases with subsequent, very difficult to predict, impacts on human health (Patz et al., 1996). Other models posit more complex pathways from climate and ecosystem transformation to adverse health outcomes including, for example, impacts of social dislocation and migration that might arise from these broad changes to ecosystems (Patz et al., 2000). Still other models focus on secondary health affects (such as malnutrition and vitamin deficiency) attendant to medium and long term adverse changes in the conditions governing agriculture and food production (Rosenzweig et al., 1993).

The magnitude of direct and indirect effects of climate change on health will be a function both of the nature and magnitude of climatic changes and the *vulnerability* of the affected populations (Woodward et al., 1998). *Thus, it is essential that research on human health effects of climate change must not only grapple with the intensity and pace of climate change but also with the location and extent of vulnerability of human populations most likely exposed to climate change* (Haines et al., 2006a, 2006b).

3.2 What will be the impact of climate change on the health of British Columbians?

Climate change will act on the health of British Columbians through physical, biological, and socio-economic pathways. It is likely that the physical pathways will be the easiest to investigate, monitor, and attribute to climate change. It is also likely that the socio-economic pathways by which climate change impacts human health will be the most complex to investigate and monitor and the most difficult to attribute to climate change. However, these socio-economically mediated health impacts of climate change will likely have the greatest impact on the health of British Columbians.

While there is strong evidence for shifts in climate in BC, *there is virtually no direct evidence yet available on the impact of climate change on human health in BC.* However, it is possible to extrapolate (somewhat tentatively) from some of the evidence, mainly restricted to the direct impacts of climate change, to suggest ways in which climate change could impact human health in this province.

The effects of climate change are likely to be complex and far-reaching, and their impact on health, diverse (Patz et al., 2005; Wilkinson et al., 2007; Haines et al., 2006a; IPCC Secretariat et al., 2007). The pathways between climate change and health that have been most investigated are exposures to extreme heat and the physical hazards resulting from extreme weather events, including those resulting in floods, fires, storms, and shifting (or entirely new) distribution of infectious diseases.

3.2.1 Physical changes that will influence health include greater exposure to fire and flood and increased exposure to heat and air pollution. Heat exposure has been studied in the United States and Northern Europe mainly in relation to urban heat waves (Semenza et al., 1996). Cities are disproportionately affected by heat because of the urban heat island effect. In major urban areas increases in temperature of up to 11°C warmer than in surrounding areas have been observed (Aniello, 1995). The impact of the urban heat island effect is magnified in

the very young and very old (Hajat et al., 2005) and for the urban elderly living in poverty (Buechley et al., 1972; CDC, 1995; Kalkstein and Greene, 1997; Nashold et al., 1996; Oke 1973). For example, during the 1995 heat wave in Chicago, there were 465 heat-related deaths and those over age 65 accounted for 70 percent of these (NOAA, 1995).

In terms of the impacts of climate related flooding, research on populations in New Orleans affected by Hurricane Katrina in 2005, demonstrated that low income, less well-educated, non-white residents of the city were most likely to sustain adverse health outcomes (Knabb et al., 2006), a result also noted from flooding in other nations (CRED, 2008). Both chronic and acute impacts of floods in BC communities will likely be greater for vulnerable sub-populations.

Heavy rainfall in coastal communities in BC is common and likely to increase in areas, with sudden runoff events which can contaminate water supplies, destabilize housing, increase injury in transport accidents, and impede access to health care and emergency services. As illustrated by recent events in Prince George, the instability of weather and increased outflow of water from melting glaciers and snowpack can create new and repeated flood risk from ice and debris jams in areas previously thought beyond the reach of the usual spring flood levels. Such floods may have even greater impact on physical infrastructure if they occurring in areas usually not prone to flooding.

Increased sediment load due to landslides or heavy runoff may also affect water quality. As recently as November 2006, over two million people in the Greater Vancouver Regional District were affected by a boil-water advisory due to high sediment load in one reservoir. Boil-water advisories are common; 530 were in place in BC in May of 2008 (the greatest number per capita in the country). Such advisories may be only a nuisance for some, but for vulnerable individuals such as those with compromised immune systems they can be deadly (Eggerston, 2008). As well, flooding and extreme precipitation contributes to water turbidity which reduces the effectiveness of drinking water purification (LeChevallier, 1981). The possibility of groundwater contamination is also increased and, given that about one quarter of British Columbians receive drinking water from this source, this poses a future health concern (BC Ministry of Environment, Land, and Parks, 1993).

Paradoxically, some regions of the province are at risk of shortages of both surface and ground water (Walker and Sydneysmith, 2007). Retreating glaciers, declining snowpack, earlier spring melt, higher evapotranspiration, shifts in the timing and amount of precipitation, and prolonged drought are expected to limit water supply during peak demand periods, and lead to increased competition among water users. Declining stream flow and groundwater levels, which also effect water quality, coupled with increased runoff due to extreme events, may lead to greater impacts from water-borne pathogens and other contaminants (Moore et al., 2007; Whitfield et al., 2002b).

Impacts of climate change on health due to fire and flood could be considerable given the complicating factor of widespread forest kill due to mountain pine beetle (MPB) infestation in northern and central regions of the province. Dead standing trees are a fire risk and also exacerbate rapid water runoff patterns in the spring, which are likely with climate change, increasing the potential for flooding and water system contamination. It is therefore likely that increased fire and flood will occur, particularly in the zones of the province affected by MPB (Patriquin et al., 2005).

In Western North America, forest fires are now more frequent and severe (Westerling et al., 2006), and are projected to become more frequent and severe in Western Canada (Flannigan et al., 2005; Gillet et al., 2004). We know also from recent fires in the towns of Barriere and Kelowna that there are direct and often severe impacts on people (Volney and Hirsch, 2005). For example, an investigation during a three week period during the 2003 fire season near Kelowna showed an increases in physician visits for respiratory diseases of between 46 and 78% above aggregate rates for the same weeks in the previous ten years (Moore et al., 2006). As well, according to Nelson Ames, Medical Officer of Health for the Kootenays Region in discussing the impact of the Kelowna fire, "cases of mental and physical exhaustion have already surfaced, and some people are exhibiting symptoms of post-traumatic stress disorder" (MacKay, 2003). Thus, the impacts of fire on health may be complex and chronic extending well beyond acute respiratory effects.

Air pollution has a well known adverse impact on respiratory health (Brauer et al., 2002, 2003). Air pollution occuring with temperature increase may potentiate adverse health impacts particularly in urban regions in BC and especially by enhancing exposure to ozone (Katsouyanni, 1993). Air pollution/temperature interactions could be further potentiated by increased particulate exposure due to wood smoke exposure from more severe and frequent forest fires (Simkhovich et al., 2008).

For vulnerable groups such as the elderly and those with existing cardio-pulmonary disease, increases in temperature in conjunction with increases in pollution pose a much greater risk to human health than exposure to these hazards on their own (Rainham and Smoyer-Tomic, 2003). Fire and heat events are likely to occur at the same time due to seasonal meteorology. Additionally, temperature increases will increase the production of ozone from traffic-related pollution. As BC ports and airports increase the levels of diesel, jet-fuel and marine emissions this climate effect could become more significant, particularly in the eastern parts of the Lower Fraser Valley that already experience significant ozone pollution (BC Ministry of the Environment, 2008).

Other indirect effects arising, for example, from secondary effects on agricultural and marine resources are difficult to assess, but it is likely that the most affected places will be those that are already environmentally and socially stressed (McMichael et al., 2003). However, there will be some regional winners in agriculture as the temperature increases in the province and these may lead to human health benefits.

For example, many scientists predict that the area of arable land and the range of crops planted will increase, at least in nations situated in temperate regions, as the earth warms. Projections for BC indicate longer growing seasons in the future (Zebarth et al., 1997), which will increase the range of crops that can be grown in BC. With a moderate climate change scenario, by 2020, it may be possible to grow cereals, cabbage and potatoes, in the central interior, and corn and tomatoes along the Fraser River valley as far north as Prince George. By 2050 these latter crops may be growable in the Peace River region (Zebarth et al., 1997). There may also be greater potential for expansion of agriculture in the Peace River region.

The impacts on human health of this expansion in agriculture could be positive by increasing food security. Other potential benefits to health from climate change are extremely difficult to predict.

3.2.2 Biological changes will arise when temperatures and precipitation increase. Water-borne diseases may increase as a result of increased precipitation and flooding (Mullens, 1996). For

example, the incidence of pneumonic infections due to the water-borne infectious agents legionellosis (which causes Legionnaires disease) is likely to increase. Legionnaire's disease and other pneumonic infections are directly related to increases in rainy humid weather, the type of changes we are likely to see in BC (Fisman et al., 2005). Many respiratory pathogens, such as influenza, exhibit winter seasonality. Some data has shown increased influenza with the arrival of El Nino patterns in the United States (Choi et al., 2006). Given that the increased temperature and rainfall associated with El Nino is likely also important to BC's future climate, this may indicate the potential for increased influenza rates in BC.

Food–borne gastroenteritis, particularly illnesses related to Campylobacter and Salmonella, currently exhibit a summertime pattern of occurrence (Bowman et al., 2003). Rises in temperature will likely see growth in the prevalence of these types of illness in human populations in BC (Gubler et al., 2001).

A rise in temperature may alter living conditions for animal and plant vectors of diseases (Patz et al., 1996). Climate change impacts vector-borne disease by increasing the range and abundance of animal or insect reservoirs, prolonging transmission cycles, and increasing the importation and range of new vectors. As noted by Wilkinson (2008), there is a risk of greater spread of a number of vector-borne diseases in many jurisdictions although more research is needed to obtain reliable predictions within the context of complex regional environmental co-factors.

The higher average rainfall and temperatures and earlier onset of spring predicted for BC could result in prolonged transmission cycles for vectors of human disease (Sutherst, 2004). Evidence is sound enough at this point to conclude that there is a risk of greater spread of a number of vector-borne diseases such as malaria to climates as far north as BC (Martens et al., 1999). In particular, higher temperatures and precipitation may extend the northern ranges of currently established vector borne disease such as Lyme disease (Ogden et al., 2008). In Europe during the 1990s, for example, a northern expansion was observed for ticks causing Encephalitis and Lyme disease (Lindgren et al., 2000) and such a phenomenon is possible in BC.

Vectors for West Nile disease include birds and insects (mainly mosquitoes). Earlier onset of spring in combination with increased temperature and rainfall increases the likelihood of mosquito infection from birds and transmission to people and will likely result in establishment and expansion of this disease in BC (Gould and Higgs, 2008; Morshed, 2003). As well, Hantavirus Pulmonary Syndrome caused by the Hanta virus carried by rodents has been expanding in BC, an increase linked to growth in rodent populations due, in turn, to warming temperatures, particularly mild winters (Drebot et al., 2000).

New fungal pathogens that originate in warmer and wetter climates may find the local soil ecology and climate more welcoming with climate change. For example, Cryptococcus gatti, a tropical fungus, first appeared in 1999 on the South East coast of Vancouver Island, an emergence that may be due to changing climatic conditions (Kidd et al., 2004). This fungus has caused over 100 cases of human illness and appears to be spreading from Vancouver Island to the Lower Mainland (Greer et al., 2008).

3.2.3 Socio-economic changes. Most of the discrepancy in chronic and physical and mental illness seen across cultural, economic, ethnic, and geographic dimensions arises as a result of social rather than biological determinants of health (Paradis, 2008). BC's vulnerable communities will likely be more heavily impacted than more robust ones, even without factoring

in the unequal regional physical effects of climate change (Woodward et al., 1998). There is a need, therefore, to focus climate change research on vulnerable populations and vulnerable communities. It will be particularly important to determine the impact of climate change among children and the elderly, as these populations are the most vulnerable to climate change (Paulson, 2007).

To the extent that vulnerable people live in vulnerable communities and given that health research and adaptive policies are usually directed at the community level, it will be important also to identify the communities most vulnerable to climate change in BC. Once identified, it will be important to prioritize research and adaptive policies towards them.

The importance of a focus on vulnerable rural and remote communities in BC cannot be overstated. First, approximately 30 percent of the province's population lives in rural and remote places (Mitura and Bollman, 2003). Second, the socio-economic conditions in most rural and remote places in BC are systematically worse than they are for urban British Columbians (Ostry, in press). Third, the health status of rural British Columbians is systematically worse across a broad range of health outcomes than for urban citizens (BC Health Atlas, 2004). Fourth, of all rural and remote communities in BC, Aboriginal communities have by far the worst socio-economic and health profiles, so that research on these communities, especially those most affected by climate change, is essential.

Fifth, rural and remote places in central and northern BC are already facing a severe climate-change related disaster, namely infestation of pine forests by the mountain pine beetle. This infestation has resulted in the death of over 90 percent of BC's pine forests (Patriquin et al., 2005). There is no argument that this is a climate change related disaster.

Rural and remote resource-dependent communities may be the most vulnerable among climate change vulnerable communities. Health effects of climate change on rural resource-dependent communities will likely arise through socio-economic de-stabilization directly arising from depletion of the main resource, particularly in vulnerable communities and communities with vulnerable populations. These effects will be magnified in these types of communities, as they are already buffeted by more adverse socio-economic winds than more diversified urban communities (Hayter, 2000; Hayter and Barnes, 1992). This double de-stabilization threat to communities will then be further potentiated because many of these communities will also be exposed to increased frequency of fires and floods (as forests infested with MPB are at heightened risk for fire), which will have dramatic and direct effects on health (Barnes et al., 2001).

4.0 A CLIMATE CHANGE AND HEALTH RESEARCH AND POLICY AGENDA FOR BC

We suggest five principles to guide development of research and policy to enhance adaptation to the health impacts of climate change in BC.

1. *Basic research is required to develop "made in BC" models and infrastructure for use in climate change and health investigations.*

There are four dimensions to investment in this type of research:

First is the need to obtain better local meteorological data, as climate monitoring networks are not adequate to measure BC's highly variable climate (Miles and Associates, 2003). It is also essential to provide appropriate downscaled climate datasets that better match the administrative areas and data boundaries utilized for most population health studies.

The second need is to develop models that apply accurate regional climate change predictions (once available) to regional topography, hydrology and ecological systems to accurately predict flood and fire risk, surface and ground water quality change, and that model the introduction and spread of new and existing vector-borne and other infectious illnesses.

Third, little research has gone into conceptualizing and designing studies to elucidate pathways between climate change and diseases that are common in BC, such as coronary heart disease, cancer, and respiratory disease. Given the high prevalence of these kinds of illnesses in BC, relatively small adverse impacts exacerbated by or due to climate change could result in fairly large increases in prevalence. Research is required, in conjunction with a better prediction of region-specific impacts of climate change, to elucidate these indirect pathways.

Fourth, in order to apply enhanced climate change and environmental impact data to improved conceptual models at the regional level, it will be essential to have good quality longitudinal health data available for research, as climate change and health studies require at least 30 years worth of data (Kovats et al., 2001). BC is uniquely positioned to be a leader in climate change and health research because of the BC Linked Health Database. This world-class health database consists of inter-linked health, socio-economic, and educational data that can be utilized in studies down to very small local areas. It is essential that these data be further developed and ways found to facilitate their availability for climate change and health research.

2. *Climate change will aggravate existing health disparities in BC, so that research and adaptive policy must, in the immediate future, be focused on rural and remote resource-dependant communities, particularly those directly affected by the mountain pine beetle infestation and in remote Aboriginal communities as well as in vulnerable urban neighborhoods.*

Action is required to enhance the adaptive capacity of the most vulnerable regions and the most vulnerable people within regions. An emerging research agenda must focus on understanding regional and community resilience, particularly among vulnerable sub-populations, in order to build on these. Research on social capital of communities, flexibility and innovation of government, private sector and non-profit agencies, and programs is needed. In short, the role of collective coordination and action in facilitating adaptation is important (Adger et al., 2003).

As well, in order to create a context where people are able to respond to multiple types of change and hence reduce vulnerability under future climate change, adaptation policy efforts need to take a broad approach to address the structures and factors that presently create vulnerability among different groups (Eriksen and Lind, 2008). In particular, climate change adaptation policy needs to be oriented towards enabling local and regional policy (Thomas and Twyman, 2005).

3. Development of adaptation policy requires education and mobilization of the public as well as health and other professionals.

The effectiveness of strategies for adapting to climate change depend on the social acceptability of options for adaptation, the institutional constraints on adaptation, and the place of adaptation in the wiser landscape of economic development (Adger, 2003). Promotion of local adaptation policies requires public and professional buy-in. This requires fostering strong collaborations with health authorities, municipalities and others responsible for individual and public health, and developing strong policies promoting knowledge transfer from researchers to stakeholders. Most importantly, adaptation strategies must be customized for local conditions and populations (US Climate Science Program, 2008).

However, mobilization of the public, government and non-government stakeholders may not be easy even in relation to climate change. For example, Leiserowitz (2006) has shown in a population-based survey of Americans, that most individuals feel that climate change is a moderate danger likely to impact people and places that are far away and of little personal importance. Lorenzoni and Pidgeon (2006) have also shown that these attitudes are largely shared by Britons and suggests that engaging the public on this issue is challenging. These attitudes are likely quite common among Canadians.

Engagement is key to moving individuals and community leaders forward in developing adaptive strategies to deal with climate change as it unfolds, because it is only when individuals in communities feel vulnerable to the impacts of climate change and understand that their community livelihood and their health may be threatened, that they will be moved to make individual changes and press their communities for adaptive strategies. A key area of research to develop is in risk perception of climate change impacts of health in order to understand regional variation in these perceptions as these will be a marker of the potential for successful adaptation polices to be enacted at the local level.

It will be essential to investigate the perceived risk of climate change relative to other life risks in relation to physical and mental health, and well-being. A focus on rural resource-dependent communities located in places where extreme weather-related climate change events are expected in the near future and in these types of communities located in the MPB zone is recommended. Comparisons of risk perception among individuals living in communities impacted by climate change and in control communities where these effects are not yet manifest, will be important.

4. *Adaptation to climate change will require development of new collaborations across government, regional health authorities, and non-government agencies as well as an enhanced surveillance role for public health authorities.*

There are five objectives of adaptation to climate change (Niang-Diop and Bosch, 2005):

These are 1) increasing the robustness of infrastructure designs, 2) increasing the flexibility of vulnerable managed systems, 3) enhancing the adaptability of vulnerable natural systems, 4) reversing trends that increase vulnerability, and 5) improving societal awareness and preparedness. These five ways of moving forward on adaptation are inherently cross-sectoral. They require new collaborations and partnerships, both horizontal and vertical, to promote adaptation.

The public health system in BC has a key leadership role to take in these collaborations. There are several reasons why. First, the public health system in place in BC (now with better support from the federal government) has the credibility, the medical and managerial skills (ranging from disease surveillance to disaster response planning), as well as experience and

engagement across ministries and sectors and at the provincial and local levels, to coordinate policies to adapt to the health impacts of climate change.

Also, several public health principles point to well established public health approaches to climate change. First, what public health professionals understand as primary prevention would be mitigation. Secondary and tertiary prevention would be adaptation (i.e., efforts to anticipate and prepare for effects of climate change thereby reducing the associated health burden). These latter categories fall under the framework of public health preparedness. The idea that steps to protect public health from threats of climate change cannot await full scientific certainty is also consistent with prevailing public health practice and management.

Public health surveillance, emergency preparedness, and research functions must be bolstered in order to take on a stronger leadership role in climate change and health adaptation policy development and implementation.

5. *Climate change will strain the provincial health service in uneven fashion across regions. To ensure equitable access to health services, a better understanding of the future impacts of climate change on health services is required.*

BC already has major challenges in ensuring equitable access to health services across its communities. As climate change is likely to produce changes in demography, changes in the health problems they experience, and widen existing disparities, the pressure to innovate in service delivery, particularly in vulnerable communities, will increase.

It is important to recognize that the specific challenges posed to the healthcare system will be different across regions. For example, the Interior will likely be the first to deal with the consequences of excessive heat. Similarly, the Vancouver Island and Vancouver Coastal Health Authorities will be first affected by the introduction of new warm weather vector-borne diseases. The impacts of heavy flooding may be particularly important for the Northern Health Authority as will be the climate change and health impacts from destabilization from already vulnerable forestry-dependent communities.

The BC Linked Health Database will be a key research resource for monitoring change in access and equitable availability to health services across regions. As a current deficiency of this database is its ability to capture health data of individuals and communities accessing services outside of the BC Health fee for service framework, many of whom live in remote or rural areas that are already bearing the health burden of climate change, this database must be further developed to improve data on impacts of climate change on health services in the immediate future.

5.0 CONCLUSIONS

To the extent that reasonably good evidence is available, it is in relation to direct effects of heat on human health, of climatically induced natural disasters, and the direct effects of increased temperature and precipitation on various pathogens and disease vectors. In all cases researchers have noted that effects on human health will always be greater among those subpopulations that are most socio-economically vulnerable.

The indirect and distal effects of climate on human health acting, for example, through destabilization of communities and agriculture, which are very difficult to study, measure, and attribute exclusively to climate change, will likely be most important in terms of their population-attributable risk. In other words, the methods, models, and evidence base to investigate climate change and health links and outcomes that matter most for British Columbia are, at present, under-developed and speak to the need to invest resources and infrastructure to build the necessary evidence base.

Based on our review of the impacts of climate change on health in BC we, in the previous section, outlined five principles that should guide development of research and adaptation policy in this realm and we recommend that government move on these quickly.

Finally, extrapolating from the limited evidence available on the direct effects of climate change on health, we draw policy-makers' attention to eight areas of particular concern for the province. These areas are identified because of their potential impact on public health and the importance of the development of a robust database in these areas.

1. Direct or indirect climate change-related de-stabilization of communities will have the most immediate and severe impact on the health of British Columbians.

2. It will be important to investigate the impacts of climate change in vulnerable communities, such as those currently affected by and in the future path of the mountain pine beetle infestation.

3. Communities that rely upon glacier and snowfields for their water supply are likely to face adverse health effects related to water quality as well as quantity.

4. If climate change produces more frequent and more severe fires and floods in the province, both acute and chronic illnesses in relation to these hazards will increase.

5. If fires increase, if industrial and residential pollution remains the same or increases, interactions with increased temperatures may lead to increases in respiratory and cardiovascular disease.

6. The frequency of heat events are likely to increase in BC and will be significant for vulnerable populations in the interior.

7. The prevalence of vector-borne illnesses already established in the province will likely increase as temperatures and precipitation increase in BC.

8. Some, as of yet unknown number and type of illnesses with vectors from warmer and wetter climes may be introduced and establish themselves in BC as the climate changes.

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