Confronting Climate Change in the Great Lakes Region
Technical Appendix

Climate Change and Human Health

This document, written by Mark L. Wilson and George W. Kling, University of Michigan, is a technical appendix providing further detail on human health-related information in the Report on **Confronting Climate Change in the Great Lakes Region** *available at* www.ucsusa.org/greatlakes/ (Kling et al. 2003).

Many concerns over global change can be linked to the health and well-being of humans. Our welfare is intimately tied to that of our environment, resource base, and common home. Health effects can be traced from many factors, including changes in water resources, forests, agricultural production, atmosphere, and most other domains that will be affected by climate change. However, here we focus on those health impacts that are related to respiratory diseases and severe weather events or extreme heat, and infections diseases. Although it is recognized that health may be impaired by climate-related changes in the economic infrastructure, production of nutritious foods, loss of ecosystem services, impacts on recreation, and many other socio-economic changes, discussion here is limited to the more immediate pathways.

Risks from Air Pollution to Respiratory Diseases

Climate variability and eventual climate change impacts on the region affect the quality of the air that people breathe. Diverse evidence indicates that ground-level air pollutants such as ozone and various particulates exacerbate asthma and other respiratory illnesses (Swift and Foster 1999) and may even cause them (e.g., McConnell et al. 2002). Recent reports have suggested that reduced fossil fuel emissions could prevent thousands of deaths in the U.S. each year (Cifuentes et al. 2001). In some areas, gases such as sulfur dioxide, nitrous oxides, and ozone, as well as various kinds of aerosolized particulate matter, have been increasing. These will act as irritants to the respiratory system and as potential carcinogens. Some studies suggest that increased heat associated with climate change can enhance fungal spores and pollen, which in turn may enhance allergic reactions (e.g. Bernard et al. 2001, Bunyavanich et al. 2003). But associations of air quality under conditions of climate change generally are still areas requiring significant scientific research. In the upper Great Lakes region, studies of respiratory disease associated with air pollution are only beginning to appear. Definitive results on how people will be affected in this region are still outstanding, but results from other areas indicate that ill-health could occur.

Regional forecasts using two older global climate models (the CGCM1 and HadCM2) indicated that weather conditions conducive to high ozone will occur more often by the end of the 21st century (Wilson and Sousounis 2000; Sousounis et al. 2002). These studies demonstrated an expected increase in the number of days when these conditions would be present by factors ranging from 5 to 100 times present levels for Detroit, Michigan – principally because of more days with high heat (*Table 1*). Such changes will likely lead to decreased air quality and an increased incidence of respiratory disease. With the newer climate model projections used in this report, we expect these types of conditions to become more severe or more frequent, especially because projections of the newer models call for higher temperatures and often less moisture during summer.

Table 1. *Total number of days with synoptic weather conditions favorable for high ozone and heat during May through October in Detroit, Michigan using two older climate models. Both models predict an increase by the end of this century.*

Model	Years	Southwest flow	High Pressure	High heat	High ozone
		Current 20-year period			
CGCM1	1975-1994	1570	2205	10	3
HadCM2	1970-1989	1295	2162	140	22
		Future 20-year period			
CGCM1	2080-2099	1603	2171	987	377
HadCM2	2078-2097	1254	2167	582	157

Source: Wilson and Sousounis 2000.

Potential Impacts of Severe Weather Events

Potential health impacts, including physical injury, psychological stress, and even death, may result from short-term, extreme weather events. Floods, tornadoes, and blizzards are well recognized in the Great Lakes Region, and heavy precipitation events have increased in frequency over the last 100 years (*see Figure 7, p. 35, in the Great Lakes report*). Extensive precipitation that results in floods can cause immediate injury and death (unlike multi-day extreme heat conditions). Future changes in other extreme weather events are difficult to assess, and the coarse resolution of global climate models makes it difficult to forecast whether small-scale extreme events (e.g., severe thunderstorms or tornadoes) will become more frequent or intense in the future. Even if there is no change in the frequency of these events, projected increases in population and economic wealth located in hazardous areas suggest a likely increase in more direct harm to humans and property in the future. Indirect effects from drought, extreme winds, and floods may negatively impact food production, housing, drinking water, and economic infrastructure. How harmful extreme events will be in the future will be influenced by early warning and disaster preparedness, as well as by individual and community-level coping strategies.

Impacts of Heat-related Morbidity or Mortality

Diverse weather phenomena cause injury and death to humans. For example, people who lack protection from hot or cold weather extremes will suffer from disturbances of normal physiological functions. Prolonged extreme heat is associated with cramps, fainting, heat exhaustion, and ultimately heat stroke. But what is meant by "extreme" is relative, and depends partly on previous exposure that influences physiological adaptation, age, and other health conditions. Because "heat waves" may last for days or weeks, the duration may influence how people with previous exposure or different social conditions respond. Lengthy or repeated heat waves may not allow people to recover. Heat waves typically occur with little or no rain, therefore conditions of high humidity, elevated ozone, and other air pollutants (NO_2, SO_2, and particulates) otherwise “washed out” of the atmosphere may produce ill-health effects. This is especially so for people who lack adequate coping resources such as air-conditioning, swimming pools, or even income to pay the bills for cooling their living space.

In the upper Great Lakes region, most of these impacts are likely to be greatest in urban areas, especially where extremely high temperatures historically have been rare. Examples from other urban areas are illustrative (Martens 1998), such as in Chicago when many people died during a 1999 summer heat wave when temperatures reached and stayed at or above 99 °F for days (Currie 1999). But, heat waves are not new to Chicago, and in 1995 an estimated 514 heat-related deaths, mostly of them elderly people, occurred during a heat wave in the Chicago area (Semenza et al. 1996; Whitman et al. 1997). Such impacts from heat stress may be reduced through appropriate behavioral changes such as use of air conditioners, wearing light clothing, and drinking lots of water. The nighttime low temperatures may be more important than the daytime high temperatures, particularly in urban areas (Klinenberg 2002). Because some people (especially the poor, elderly, and very young) tend to be less resistant to extreme temperatures, they are more susceptible to these extremes (e.g., McGeehin and Mirabelli 2001). Others who work outside or who lack access to indoor cooling also are at greater risk. People who remain indoors because of fear of crime or because they are bed-ridden with few social contacts are also highly vulnerable.

In the Great Lakes report (Kling et al. 2003), the Hadley 3 global climate model was used to estimate temperature extremes in the Great Lakes region through 2100. As expected, the number of hot days increases throughout the period (*see Figure on right*), with many years likely to experience 40 or more days exceeding 90 ºF (32 ºC) by the last few decades of the century. Of greater concern is the forecasted number of days with extremes reaching 104 ºF (40 ºC) or more. The new climate models are suggesting more extreme temperatures being reached on more summer days than previous estimates.

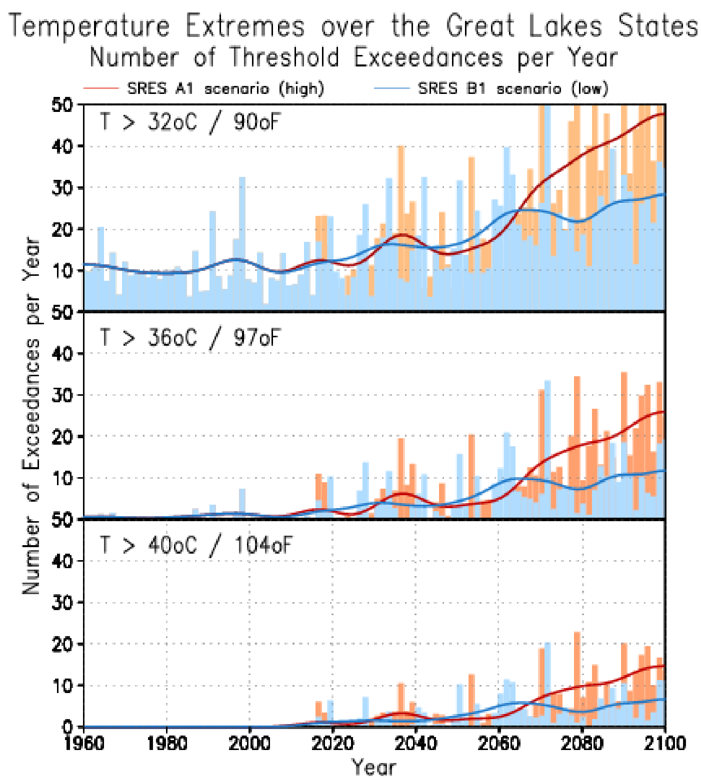

***Figure 1.** Days of extreme summer temperatures will increase in the next century (based on analyses of model results from the Great Lakes Report, Figure 32A).*

Impacts from Infectious Diseases

Links between climate change and infectious diseases are very complex and hardly any studies have been published for the Great Lakes Region. Thus, our understanding about specific regional impacts remains tentative, given the complex pathways by which the climate affects the survival and abundance of infectious agents, human populations and behaviors, and other indirect modes of transmission that may involve non-human vertebrate reservoirs and arthropod vectors (e.g., Patz and Lindsay 1999). We can, however, with some caution extrapolate from those conditions that tend to be conducive to greater distributions or abundances of vectors and reservoirs. Whether these conditions alone constitute risk, and how to anticipate that risk over what time frames, are difficult questions that presently remain unanswered. While this problem applies to the link between climate change and health, it is also true for that between health and increased climate variability. Indeed, we are aware of very few studies underway intended to explore how variation in temperature, precipitation, or other weather variables may be related to the incidence of infectious diseases in the Great Lakes Region. One such study, undertaken in collaboration with the Michigan Department of Community Health, involved time-series analysis of case data for viral meningitis from 1993-2001 (Greene et al. *unpublished*). Although other epidemiological and spatial patterns were identified for this human-to-human or water-borne infection, no climate-related associations were detected. The temporal pattern of many other infectious diseases, however, is strongly seasonal or related to extreme weather events, suggesting that climate may be a factor that influences transmission intensity. However, it will be necessary to undertake more extensive time-series analyses to better understand these patterns of disease that vary in space and over time.

Nevertheless, it is possible to anticipate that the risk of certain climate-sensitive diseases might increase with greater climate variability or gradual climate change. Some water-borne infectious diseases such as cryptosporidiosis or giardiasis may become more frequent or widespread if there are more extreme precipitation events (*Figure 7 on p.35 in the Great Lakes report;* Curriero et al. 2001) or if water treatment facilities are overwhelmed. Some vector-borne diseases such as Lyme disease or West Nile virus fever have recently expanded in the Great Lakes Region, and continued increases in range or frequency of transmission could occur if changes in precipitation or temperatures encourage vector reproduction or survival. Interestingly, more extreme precipitation events may actually decrease abundance of the specific vector ticks and mosquitoes, but the combination of long dry periods and heavy downpours – as projected for the Great Lakes Region as climate change proceeds – has been associated with increased vector abundance in other regions.

Outlook

Perhaps the most important health impacts of climate change will operate through indirect pathways in which basic human needs are affected. The economic changes that are expected from climate change (but also independently) could be significant, and alter people's access to treatment, safe housing, adequate food, and even safe drinking water. The impacts on social structure and community infrastructure will certainly change healthy behavior, treatment capacity, and prevention. Any societal or environmental change that alters jobs and income could produce such indirect effects on many health-related sectors.

The current challenge is to anticipate how these processes will reverberate through various sectors, social classes, geographic regions, and life styles as they impact on human well-being. Simple models are inadequate. Linear projections are certainly going to be misleading. The challenges of identifying how climate change will impact health, let alone all sectors of society for generations to come, are enormous.

Implications for Future Research

Although the long-term forecasts for environmental change are becoming increasingly accepted, inadequacies and uncertainties in the effects on health indicate that extensive research efforts are needed to understand links and eventually develop minimization and management strategies (e.g., McMichael 1996; Chiotti et al. 2002). The diversity of ecological systems that are involved, the many decades during which climate changes are likely to occur, and the uncertainty of how interactions will alter the risk of disease all complicate forecasts. Not only is more research in these areas needed, but we also require a shift in the nature of these investigations. Rigorous study of historical patterns is needed that uses long-term disease surveillance data to look for variation with climate. However, for many diseases the currently available data are inadequate for such investigations. Because many important processes involve interactions among diverse variables (e.g., human physiology, economic policy, microbiology), new theory and analytic tools are needed. Such new research efforts should not only incorporate these interactions, but must analyze climate variability as part of a much larger arena of environmental change.

Many recent reports have made abundantly clear that disease surveillance in the U.S. is inadequate (e.g., Committee on Climate, Ecosystems, Infectious Disease and Human Health 2001). A new research agenda will require systematically gathered epidemiological records. We currently lack much of the basic information needed to analyze even past variation in disease patterns. Such data are critical to investigation of disease trends, analyzing retrospective analysis of environmental change associations, and eventual prediction and modeling of future outbreaks. New research could also focus on identifying disease-specific approaches that help to prevent outbreaks before they occur. Among the most likely environmental drivers are various climate variables that can be used as predictors and that will help in designing preventive strategies.

In order to improve disease forecasts new methods for analyzing data and interpreting patterns are needed. This is because the many complex interactions among physical (climate), biological, and socioeconomic variables require more multidisciplinary approaches. The role of traditional disciplines such as climatology, immunology, or physiology, remain important, but experts increasingly appreciate how health is co-determined by social, behavioral and economic factors. Innovative methods are needed to address these needs for a multidisciplinary approach. They may involve investigations of disease ecology during environmental change using spatial statistics, theoretical studies of complex dynamic behavior, or integrative modeling of socioeconomic development impacts on pathogen transmission. These methods may also find that the role of income and education in the ability to cope with climate-related changes in disease risk is a critical factor.

Implications for Prevention

The manner in which public health agencies can prepare for changing patterns of disease threats resulting from climate change will depend on the causes of each condition (e.g., Chan et al. 1999). For example, extreme heat events are generally easy to forecast and thus strategies can be implemented to prevent the resulting morbidity and mortality. If the frequency or intensity of extreme heat events increase in the future, earlier forecasting, information distribution, and assistance directed at high-risk populations could reduce the increased disease risk. Although it is possible that people can adapt physiologically over many years, most heat stress occurs during short-term extreme events making adaptation less likely. Critical to reducing heat-stress mortality will be improved economic well-being and education of the elderly and poor so that they may better cope through increased use of fluids and air conditioning. Other services for sick or bed-ridden people and those living alone may also be required.

The effects of other extreme weather events such as tornadoes or floods could also be lessened if there were better forecasting and advance warning. Such knowledge can allow people to take actions to reduce risk and allow disaster relief to prepare responses. Obviously, limiting construction of dwellings on flood plains and strengthening building codes play a big role in reducing risk of flood damage and deaths. Improved storm drainage systems, and warnings to avoid high-risk areas might also reduce contacts with infectious disease agents.

Reducing the impacts of air pollutants on health could be achieved through earlier warning of severe conditions. The elderly or others with preexisting respiratory conditions should be told to reduce time spent outdoors during times of stagnant air associated with increased ground-level air pollutants. Most importantly, of course, will be efforts to reduce air pollutants, i.e., the source of the problem.

Links between climate variability and infectious disease risk are different for each disease, but for some diseases the link can be very important. Many infectious diseases are highly seasonal or episodic (related to extreme events) such that periods of elevated risk may be better anticipated. Although vaccines are available for some such diseases (e.g., influenza, rabies, Lyme disease), they cannot be considered an entirely safe protection for everyone because the risk and susceptibility varies among people. Particular behaviors place some people at higher or lower risk, suggesting that education and behavior changes could result in increasing the effective prevention. For example, risk of many vector-borne diseases of the region (e.g., Lyme disease, Eastern Equine Encephalitis, West Nile fever) can be reduced significantly by modifying outdoor activity, clothing, or housing. Thus, the actual effect of climate change on risk of many infectious diseases depends on diverse behavioral and economic factors, as well as biophysical ones. These diverse relationships must be considered in any plan for disease prevention.

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