The Impact of Climate Change on Vector-Borne Infectious Diseases

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Abstract

Climate change is an occurring phenomenon that creates extreme weather patterns and global warming. These extreme weather patterns and global warming have a direct negative impact on infectious diseases, especially vector-borne infectious diseases. Malaria is one of the vector-borne infectious diseases that are particularly affected by climate change for it is extremely sensitive to meteorological conditions. This extreme sensitivity is creating a resurgence and redistribution of the malaria vector, the mosquito. This resurgence and redistribution of the mosquito puts an extra pressure on the public health system, especially the public health infrastructure of a developing country. An integrated framework assessment is needed for the public sector to determine the risks of climate change on infectious diseases. Infectious disease may not have affected most developed countries as they have developing countries, but with climate change this dynamic is rapidly shifting and must be addressed. The key to the integrated framework assessment is the understanding that infectious diseases have multiple disease determinants that are not just biological, but ecological, sociological, and epidemiological.

1. Introduction

1.1 Climate Change

Climate, as defined by Chan et al (1999), is “the average weather, described in terms of the mean and other statistical quantities that measure the variability over a period of time and possibly over a certain geographical region” (p. 329). Within the 20th century, the cooling trend of the last 1,000 years has been reversed due to greenhouse gases being trapped in the atmosphere and the average temperature has risen by 1˚ C (Epstein, 2001). In fact, the amount of carbon dioxide has always been between 180 to 280 ppm in the atmosphere, but today it is 336 ppm, surpassing the rates observed in the ice core records (Epstein, 2001). As a result of climate change, global warming is taking place, which happens to occur twice as fast during the night-time in winter and at high latitudes in the winter; also the oceans are warming up to 3km down (Epstein, 2001). Global warming, in turn, is increasing the occurrence of extreme weather events; this combination of weather instability and warming is making an impact on infectious diseases, namely their vectors and hosts (Epstein, 2001).

According to Epstein (2001), “climate is a key determinant of health;” and, “climate constrains the range of infectious disease, while weather affects the timing and intensity of outbreaks” (p. 747). The World Health Organization has reported that since 1975 over 30 new diseases have appeared including AIDS, Ebola, Lyme disease, Legionnaire’s disease, toxic Escherichia coli, a new hantavirus, and a rash of rapidly evolving antibiotic-resistant organisms (Epstein, 2001). In addition, there has been a resurgence of old diseases such as malaria and cholera (Epstein, 2001). Of course, a resurgence and redistribution of infectious diseases is partly due to the deterioration of the public health system, but infectious diseases that involve two or more species, such as malaria (humans and mosquitoes), “reflect changing ecological and climatic conditions as well as social changes” (Epstein, 2001, p.748)

1.2 Infectious Disease

There are two categories of infectious diseases based on the mode of transmission: directly spread infectious diseases, meaning person to person, or indirectly spread infectious diseases through either vector organisms, such as mosquitoes and ticks, or non-biological vehicles, such as water and soil (McMichael et al, 2003). There are three great transmissions between humans and microbes that are recognized. The first being early human settlements that enabled enzootic species to enter the human species. The second being the early Eurasian civilization that came into contact through military and commercial endeavors about 2000 years ago, spreading dominant infections. Finally, the third great transmission involved European expansionism over the past five centuries that caused a transoceanic spread of infectious diseases (McMichael et al, 2003).

McMichael (1993) states it very well in his book, Planetary Overload: Global Environmental Change and the Health of the Human Species:

> The use of bed-nets influences which particular African villagers get malaria, but, in a warming world, it will be the climate-related expansion of the malarial mosquito's habitat that primarily determines which populations have endemic malaria.

There is a very limited climate range for vector species regulated by precipitation, sea level, wind, and sunlight (McMichael et al, 2003). According to Chan et al (1999), changes in the prevalence of infectious diseases are "mediated through biological, ecological, sociological, and epidemiological processes" (p. 329). And thus there is a multitude of ever changing disease determinants (Chan et al, 1999).

1.5 The Thesis

This paper is trying to define a framework to assess the impact of climate change on vector-borne infectious diseases. A framework is necessary for the public health sector to determine the risks of epidemics in different demographics and geographic regions. Malaria is an interesting vector-borne disease for it brings up the issue of developing countries versus developed countries in terms the differences in capabilities to handle epidemics stemming from climate change.

The range and transmission of mosquitoes has been affected by global warming, mostly in developing countries. So far the U.S. has not seen much public health affects from climate change, but this will change if global warming continues as predicted. Diseases like malaria that are no longer seen in Europe and the U.S. could possibly migrate further north and create huge epidemics. If the public health infrastructure does not anticipate the effects of climate change on infectious diseases, millions of people could die. Climate change is a global issue and must be dealt with before things go irrevocably wrong.

2. Results and Discussion

2.1 Mosquito Vectors and Range Expansion

As stated by Epstein (2001), "diseases carried by mosquito vectors are particularly sensitive to meteorological conditions" (p. 748). So "temperature thresholds limit the geographic range of mosquitoes;" an example being that extreme heat kills mosquitoes, but warmer temperatures, within their survival range, increases their reproduction rate, biting activity, and the rate at which pathogens mature within them (Epstein, 2001, pg. 748). *Anopheles* mosquitoes are the carriers of malaria and live only a few weeks, their transmission of malaria takes place when temperatures exceed 16 ˚C (Epstein, 2001). This extreme sensitivity to seasonal patterns explains how rainfall can increase the number of mosquito breeding sites, while dry periods can eliminate these breeding sites, but at the same create new habitats for mosquitoes (Patz et al, 2004).

It is predicted that global warming will increase the area of malaria transmission from 45% of the world's population to 60% (Epstein, 2001). For example, *Anopheles* mosquitoes used to be found in North America, but by the 1980s were restricted to California, however, since the 1990s small outbreaks occurred in Texas, Georgia, Florida Michigan, New Jersey, New York, and Toronto during extreme hot conditions weather (Epstein, 2001). Since the planet's average temperature has increased by 1˚C, plants, insects, and insect-borne diseases are migrating to higher elevations (Epstein, 2001). In fact, the word malaria comes from European colonists who settled in the highlands of Africa in the 19th century fleeing from lowlands that were known as 'mal arias' (Epstein, 2001).

2.2 Disease Determinants

There is a wide disparity between the developing world and the developed world in regards to the incidence of diseases; forty percent of the population in the developing world and only two percent of the developed world is infected with at least one infectious disease (Chan et al, 1999). This disparity between the developing and developed world is mainly due to socioeconomic conditions though the gap might become narrower with climate change (Chan et al, 1999). However, developed countries are able to afford public health programs to protect themselves from an epidemic. There are a massive amount of disease determinants that are ever changing due to the "complexity of many indirect feedback interactions or mechanisms" on climate change (Chan et al, 1999, p. 330). For example, one can improve socioeconomic levels, by reducing the breeding sites for mosquitoes, but this can also cause deforestation and in turn an increase in the contact between humans and mosquitoes (Chan et al, 1999). Also higher temperatures could increase or reduce the survival rate of mosquitoes; it all depends on their ecology behavior, and many other factors (Patz et al, 2004).

2.3 Integrated Framework

The paper by Chan et al (1999), An Integrated Assessment Framework for Climate Change and Infectious Diseases, proposes a way to identify the indirect interactions and mechanisms, recognize the research gaps, and integrate the research to better understand the whole system of climate change and infectious diseases. Climate change not only brings ecological changes such as an alteration in the range and abundance of a species, but also biological and social changes (Chan et al, 1999). This, in turn, impacts epidemiological outcomes, such as mortality and morbidity rates (Chan et al, 1999). And so this combination between the ecological, sociological, epidemiological, and biological is the best way to create an “integrated assessment framework for evaluating research on the association between climate change and infectious diseases” (Chan et al. 1999).

Ecological changes include biodiversity loss, community relocation, and nutrient cycle changes; sociological changes include migration, nutrition, sanitation, and population; epidemiological changes include host physiology, and disease morbidity and mortality; and finally changes in transmission biology include vector dynamics and pathogen dynamics (Figure 1, Chan et al, 1999, pg. 331). The above links between climate change and infectious diseases clearly indicates a multitude of disease determinants, making it difficult to study. Thus, there hasn’t been much research on the subject and most of the research found is on transmission biology and not on ecological and sociological factors (Chan et al, 1999).

Studies on ecological changes and infectious diseases discuss habitat destruction, while studies on sociological changes and infectious diseases focus on economic developments, such as nutrition and sanitation (Chan et al, 1999). Therefore, the integrated assessment framework, in the paper by Chan et al (1999, p. 335):

> Provides a means by which cross-disciplinary research could be integrated to identify, target, and initiate investigation in a number of areas, including: systematic understanding of ecologic and epidemiologic responses to climate changes; potential effects of climate changes on food and water supplies; effects of resource availability on human demographic changes (e.g., migration, urbanization), and vice versa; confounding effects of travel, habitat loss and pollution; potentially mitigating effects of increasing wealth, sanitation, nutrition, and disease control, or divergence in standards of these among human populations; effects of human activities on ecosystems; and urbanization and patchy or heterogeneous dynamics.

3. Conclusions

Climate change is occurring and is impacting ecological, biological, epidemiological, and sociological systems that human life depends on, but the degree of this impact is not known because the variables are interrelated and numerous (Patz et al, 2004). There is also a huge dependence on a strong public health system to adapt to the changing risks of vector-borne diseases (Patz et al, 2004). It makes sense then that developing countries with a poor public health system are at a higher risk to health problems that are intensified by climate change; this was also found to be the case within poor populations in the United States (Patz et al, 2004). Consequently a dialogue must take place between developing and developed countries with regards to climate change and its impacts on health risks.

The evidence that global warming is an existing force is mounting for the overall trends in regards to glaciers, plants, insects, and temperatures is pointing in one direction and that is a reduction of glaciers, an increase in overall temperatures, and a range expansion of insects and plants (Epstein et al, 1998). Epstein et al (1998, p.415) says it most succinctly:

> Human activities are altering atmospheric chemistry and changing the earth's heat budget. Together, these chemical and physical changes—compounded by large-scale land use and land-cover changes—have begun to affect biological systems.

> The public and policy makers must be increasingly concerned with the biological consequences and societal costs associated with climate change.

The key to combating the issue of climate change and infectious diseases is to recognize the circular connections between the vector and the biological, ecological, epidemiological, and sociological changes. The multiple disease determinants stress an approach that is multi-faceted and supported by both the developed and developing world.

4. References

Chan, N.Y., Ebi, K.L., Smith, F., Wilson, T.F., and, Smith, A.E. (May 1999). An Integrated Assessment Framework for Climate Change and Infectious Diseases. Available: Environmental Health Perspectives. 107. 329-337 [April 4, 2007].

Epstein, P.R. (2001). Climate change and emerging infectious diseases. [Online]. Available: Microbes and Infection. 3. 747-754 http://www.cse.polyu.edu.hk/~cekslam/Paper/science14.pdf [April 4, 2007].

Epstein, P.R., Diaz, H.F., Elias, S., Grabherr, G., Graham, N.E., Martens, W.J.M., Mosley-Thompson, E., and Susskind, J. (March 1998). Biological and Physical Signs of Climate Change: Focus on Mosquito-borne Diseases. [Online]. Available: Bulletin of the American Meteorological Society. 79. 409-417 http://www.decvar.org/documents/epstein.pdf.html [April 4, 2007].

McMichael, A.J., Campbell-Lendrum, D.H., Corvalan, C.F., Ebi, K.L., Githeko, A.K., Scheraga, J.D., and Woodward, A. (2003). Climate Change and Human Health: Risks and Responses. [Online]. Available: http://books.google.com/books?hl=en&lr=&id=tQFYJjDEwhIC&oi=fnd&pg=PR1&dq=global+climate+change+impact+on+health&ots=PoBzWMV0Yf&sig=2phagZt5FpBqPQftQFWUcn-VOLA#PPP1,M1.html [April 4, 2007].

McMichael, A.J. (1993). Planetary Overload: Global Environmental Change and the Health of the Human Species. [Online]. Available: http://books.google.com/books?hl=en&lr=&id=3CqsWqDla6gC&oi=fnd&pg=PP15&dq=global+climate+change+impact+on+health&ots=xIUrsqMCmt&sig=WU4D6MB6rELdtu_SXA9d0XbaoOQ#PPA40,M1.html [April 4, 2007].

Patz, J.A., McGeehin, M.A., Bernard, S.M., Ebi, K.L., Epstein, P.R., Grambsch, A., Gubler, D.J., Reither, P., Romieu, I, Rose, J.B., Samet, J.M., and Trtanj, J. (April 2000). The potential health impacts of climate variability and change for the United States: executive summary of the report of the health sector of the U.S. National Assessment. [Online]. Available: Environmental Health Perspectives. 108. 367-376 http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1638004.html [April 4, 2007].

5. Figures

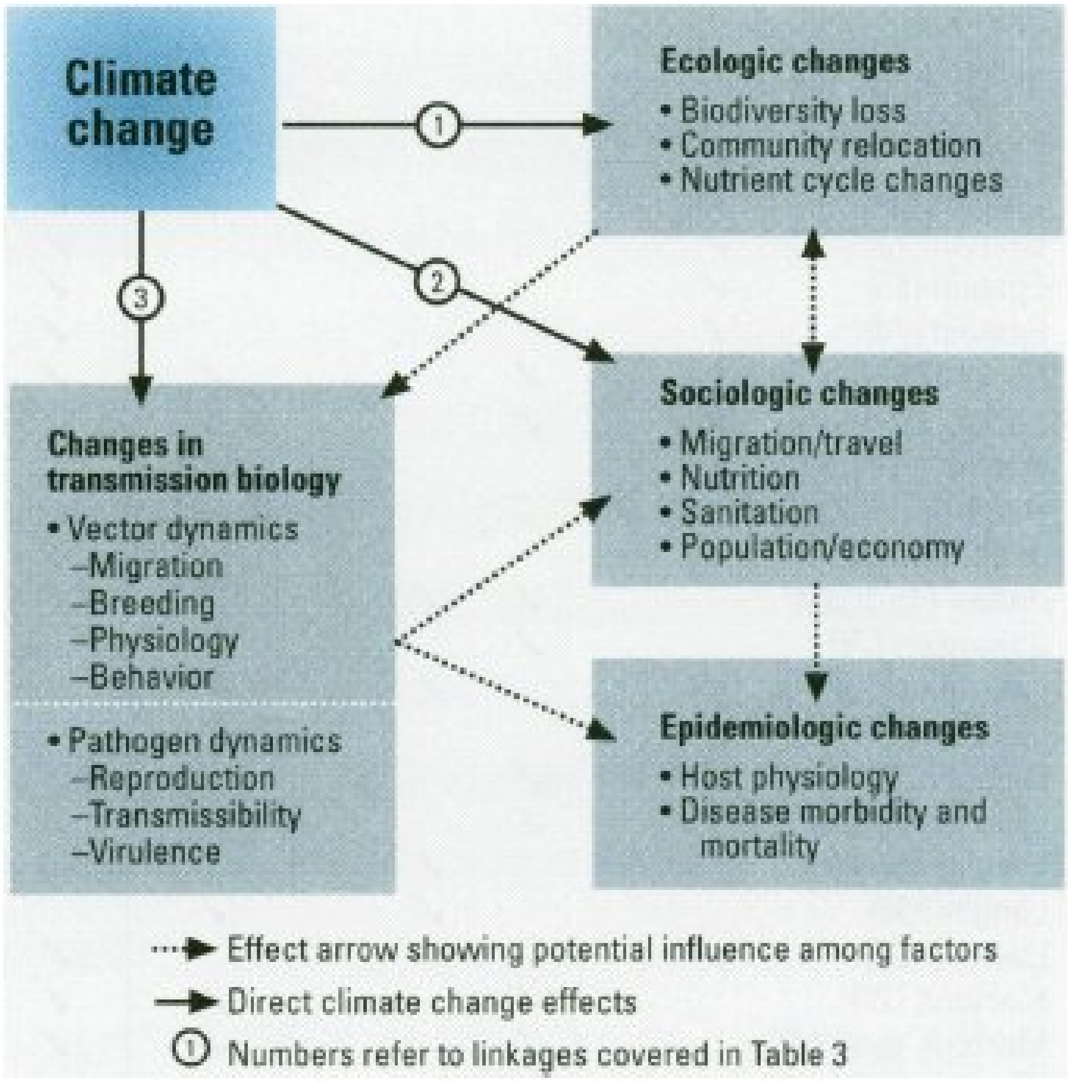

Figure 1. Integrated assessment framework for evaluating research on the association between climate change and infectious diseases. See Figure 2 for detailed links 4–13.