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REVIEW ARTICLE

Global Warming and Infectious Disease

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Global warming has serious implications for all aspects of human life, including infectious diseases. The effect of global warming depends on the complex interaction between the human host population and the causative infectious agent. From the human standpoint, changes in the environment may trigger human migration, causing disease patterns to shift. Crop failures and famine may reduce host resistance to infections. Disease transmission may be enhanced through the scarcity and contamination of potable water sources. Importantly, significant economic and political stresses may damage the existing public health infrastructure, leaving mankind poorly prepared for unexpected epidemics. Global warming will certainly affect the abundance and distribution of disease vectors. Altitudes that are currently too cool to sustain vectors will become more conducive to them. Some vector populations may expand into new geographic areas, whereas others may disappear. Malaria, dengue, plague, and viruses causing encephalitic syndromes are among the many vector-borne diseases likely to be affected. Some models suggest that vector-borne diseases will become more common as the earth warms, although caution is needed in interpreting these predictions. Clearly, global warming will cause changes in the epidemiology of infectious diseases. The ability of mankind to react or adapt is dependent upon the magnitude and speed of the change. The outcome will also depend on our ability to recognize epidemics early, to contain them effectively, to provide appropriate treatment, and to commit resources to prevention and research.

Key Words: Global warming, Infectious diseases, Climate.

"In nature there are neither rewards nor punishments; there are only consequences"

—Robert Green Ingersoll

Introduction

The Swedish chemist, Svante Arrhenius, first predicted global warming in 1896 (1). Since then, it has been a hotly debated topic among scientists, politicians and environmental experts alike. Global warming is a gradual process that threatens to have serious consequences over time, including elevated sea levels, crop failure and famine, changes in global rainfall patterns, changes to plant and animal populations, and serious health effects. Infectious diseases are global entities that depend dynamically on the interaction between the population and the existing regional climate. Thus, global warming may result in a considerable shift of the spectrum of infectious diseases. This review will introduce the basic concepts of global warming, focus on the presently available literature regarding the impact of climatic changes on human health and infectious disease, and present a possible picture of the things to come. The available literature about the future of global warming is a compendium of intelligent and logical guesswork based on experience with previous climatic trends and mathematical models of future climatic change. Lastly, some experts believe that global warming is not as malevolent as it is commonly thought to be and might actually have beneficial aspects. This viewpoint will also be explored in the course of the review.

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Global Warming—The Concept and Consequences

The concept of global warming requires a basic understanding of the greenhouse effect. Solar radiation passes through the atmosphere and is absorbed at the Earth's surface. This heat is lost from the earth's surface as infra-red radiation. The infra-red radiation cannot escape the atmosphere as easily as the solar radiation enters. Some of it is trapped by a number of gases which act similar to the glass in a greenhouse—heat can enter but cannot exit—resulting in the Greenhouse Effect. The mathematician and scientist, Jean Baptiste Fourier, first coined the term greenhouse effect in 1827 (2). In nature, the greenhouse effect is responsible for elevating the Earth's temperature, making it possible for life to thrive.

Greenhouse gases (3) include carbon dioxide, methane, nitrous oxide, hydrocarbons, perfluorocarbons and sulfur hexafluoride. Carbon dioxide, methane and nitrous oxide are naturally occurring, whereas hydrocarbons (hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) and their derivatives are generated artificially.

HFCs and PFCs are the most heat absorbent. Methane and nitrous oxide absorb more heat per molecule than carbon dioxide. Nature's defense against many of these greenhouse gases is a sink, which is a reservoir that takes up a chemical product from another part of the cycle. Soil and trees act as natural sinks absorbing hundreds of billions of tons of carbon in the form of CO_2 (3). Needless to say, activities such as uncontrolled deforestation enhance global warming and could ultimately court an environmental disaster.

Population size and global warming are related because human activities increase production of greenhouse gases. This effect culminates in global warming. The observed rise in global temperature over the 20th century was 0.3° to 0.6°C and this rise is predicted to accelerate (4). The warmest years in descending order were 1987, 1988, 1983, and 1980 (5).

To explore long-term trends in global temperatures, Easterling et al. (6) analyzed monthly averaged maximum and minimum temperatures and the DTR (diurnal temperature range) at 5400 observing stations around the world. Each time series from each station was subjected independently to homogeneity analyses and adjustments according to recently developed techniques. The observed trend for maximum temperature was an increase of +0.82°C per 100 years, for minimum temperature was an increase of +1.79°C per 100 years; the DTR trend was an increase of −0.79°C per 100 years. They explained the positive and negative DTR trends as having resulted from daily minimum temperature increasing at a faster rate and decreasing at a slower rate than the daily maximum temperature, respectively. Jones et al. (7) also examined rural-station temperature data for European parts of the Soviet Union, eastern Australia and eastern China and reported similar observations.

According to the U.S. Environmental Protection Agency (EPA), the sea level has risen 6–8 in. globally and worldwide precipitation has increased by about 1% during the past century. The EPA also noted a 5–10% increase in precipitation over the U.S. and a 10–15% increase in rainfall over the northern tier states and southern Canada over the last century. The main domain of this precipitation increase was eastern Canada and the adjacent northern regions of the U.S. (8). Increasing concentrations of greenhouse gases are likely to accelerate the rate of this potentially detrimental climate change.

Rising temperatures are likely to continue. It is predicted that the average global surface temperature could rise 0.6–2.5°C in the next 50 years, and 1.4° to 5.8°C by the year 2100 (9). The effect on precipitation and soil moisture is uncertain. Initially, evaporation will likely increase, resulting in increased average global precipitation. However, the distribution of rainfall may become more erratic, leading to focal areas of flood and drought. If increases in temperature are sustained, it is also possible that soil moisture may be permanently lost from some areas. Some experts from Stanford University have challenged this prediction as they observed an increase in soil moisture under conditions of increased temperature (10). They hypothesize that the increased temperature results in early death of plants such as grasses and wildflowers, thus reducing the surface area for evaporation. This reduced evaporation results in increased soil moisture. Frozen soil moisture has also been used to estimate the growing season in forests and estimating their efficiency as carbon sinks. Sea levels are predicted to rise 2 ft along most of the U.S. coast.

Impact of Climate on Public Health

It is impossible to quantify the exact risk posed by climate change. With particular reference to infectious diseases, the impact depends on the complex interaction between the human host population and the causative infectious agent. Important human factors include crowding, food scarcity, poverty, and local environmental decline. Some health effects of climate change may result from indirect impacts on natural ecosystems. For example, altered climatic conditions can change the habitats of vectors such as mosquitoes or rats and affect the parasites they carry. Changing the abundance and geographic range of carriers and parasites could shift the seasonal occurrence of many infectious diseases and cause them to spread.

The effect of global warming depends heavily on the ability of humans and public health systems to adapt. Human migration and economic stresses from climate variability could threaten human settlement and seriously overwhelm the public health infrastructure. This scenario might be worsened further by malnutrition due to crop failure. Facing this complex threat makes interdisciplinary cooperation among health professionals, climatologists, environmental biologists and social scientists imperative to understand and effectively manage this threat that could result from global warming.

Renewed understanding of linkages between public health and global life-support systems is emerging in the literature (11). New collaborative efforts can confront these tough challenges through advances in preventive medicine. In much of the world, the current increasing life expectancy is likely to be blunted by increased difficulty in accessing basic requirements such as sanitation and potable water. The direct and indirect impacts of climate change on human health have a considerable toll on life, resources (natural and financial) and working manpower. Altered environmental influences would also mean courting environmental disasters such as famines and floods. It known that non-vector-borne infectious diseases—such as salmonellosis, cholera, and giardiasis—can thrive under these circumstances (12). Thus, the impact of climate change depends on several factors. Although exact predictions are impossible, there are significant areas of concern throughout the world (Table 1) (13).

Water

Water is a basic necessity and its availability is of paramount importance. Currently, 1.1 billion people do not have access to adequate supplies of safe water (14), and 2.4 billion people do not have access to adequate sanitation (15). Adjusting to new shortages and/or implementing measures to ensure supply under global warming will impose a heavy burden on the already stressed national exchequer of developing countries. Various approaches to reduce the potential scarcity of water systems as a result of climate change include policies to eliminate profiteering, efficient management of available water, improved technology, integrated agriculture policies, and urban planning and management. At the national and regional level, integrated water resource management should be prioritized. It is also important that the quality of conserved water be maintained.

Water is a core substance used for cooking, dissolution and plain consumption. The infectious disease consequences of contaminated water can be significant. Childhood diarrhea is already a major cause of premature mortality around the globe (16). Epidemics of cholera, typhoid, and similar diseases can be expected if the quality of water deteriorates. It is interesting to note, however, that effective water purification and storage attempts at the household level are superior to attempts at decontaminating water at its source. Gundry et al. (17) reviewed observational studies investigating this relationship, as well as studies of home water treatment and storage interventions. For cholera, a clear relationship was

Table 1. Major potential health impact of global warming

Continent	Major potential health impact
Africa	Reduced arable land and increase in extreme weather leading to malnutrition and overcrowding
	Increase in vector-borne disease, especially malaria with potential increase childhood mortality
	Increase in water-borne diseases, with potential increase in childhood mortality from diarrhea
	Diversion of limited health resources to cope with new stresses with resulting decreased attention paid to existing diseases such as HIV
Arctic and polar areas	Indigenous peoples lose traditional sources of food as migration patterns change and ice retreats
	Loss of polar ice affects global coastlines
	Cooling of currents that now maintain temperate climates in Europe and North America
Australasia	Increased heat-stress mortality
	Increase in selected vector-borne diseases such as dengue and malaria
	Loss of coastline and fishing sources
	Increase in water-borne diseases, especially in impoverished areas
	Reduced air quality resulting in respiratory diseases
Europe	Increased heat-stress mortality
	Reduced air quality resulting in respiratory diseases
	Potential expansion of vector-borne diseases such as encephalitis
Small Island States	Potential to introduce/expand cholera, dengue
	Loss of coastal land
	Changes in fish populations resulting in malnutrition
Latin America	Potential increase in vector-borne diseases, including Chagas' disease and malaria
	Potential expansion of water-borne diseases including cholera
	Increase in air pollution and high concentrations of ground level ozone resulting in respiratory diseases
North America	Increased biting season for vectors and associated increase risk of vector-borne diseases such as encephalitis
	Reduced air quality and increased respiratory diseases
	Loss of coastline, increased extreme weather events resulting in diversion of economic resources away from existing public health efforts
Temperate Asia	Potential expansion of vector habitat including malaria-bearing mosquitoes and schistosome-spreading snails
	Increase in water-borne diseases, especially in impoverished areas
	Reduced air quality increasing respiratory diseases

found with contaminated water. Home water treatment and storage interventions were also found to reduce cholera. For general diarrhea, no clear relationship was found with point-of-use water quality, although interventions significantly reduced the incidence of diarrhea. However, they emphasized the simultaneous need for improved public education about water sanitation. Esrey et al. (18) reviewed 144 water and sanitation interventions conducted in various developing countries and in the U.S. to look at the effect improved water supply and sanitation facilities had on ascariasis, diarrhea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. They showed that improved water supply and sanitation result in substantial reductions in morbidity from diarrhea (26%), ascariasis (29%), guinea worm infection (78%), schistosomiasis (77%), trachoma (27%) and a median reduction of 65% in diarrhea-specific mortality and 55% in general child mortality. They recommended that nearby water supply and hygienic practices be integrated into water supply and health programs.

Food

Currently, 800 million people are malnourished (19). As the world's population increases, food consumption is expected to double over the next few decades. Increased demands for food have indirectly exacerbated global warming risks. Problems associated with intensifying production on land already in use are becoming increasingly evident (20). Expanding the amount of cultivable land is an option for increasing total crop production but could lead to increased competition for land, strain on natural resources, increased greenhouse gases, and reduced natural sinks of carbon as a result of ensuing deforestation.

The main direct effects of global warming will be through changes in temperature, precipitation, length of growing season, and timing of extreme or critical events relative to crop development, as well as through changes in atmospheric CO_2 concentration (which may have a beneficial effect on the growth of many crop types) (21,22). Middle to high latitudes may experience increased productivity, whereas the tropics and subtropics are likely to face decline in yields. The livelihoods of farmers and pastoral peoples, who make up a large portion of rural populations in some regions, could be negatively affected. Regionally decreased rainfall is likely to compromise agricultural production significantly. Adaptation options include changes in crops and crop varieties, biotechnically or genetically developed new crop varieties, changes in planting and reaping schedules, and improved water and irrigation systems availability and development. Other factors influencing the vulnerability of agricultural production are per capita income, the fraction of economy that is dependent on agriculture and preexisting land conditions.

Malnutrition is an important vulnerability factor for infectious disease. As stated above, global warming is predicted to reduce arable land (due to increasing sea levels) as well as making presently available land more hostile to crop cultivation. In the face of a growing population, this would amount to lesser availability of food and under-nutrition. Climate change could also affect food production, with concentrated decline in low-latitude regions where food insecurity often already exists, including Africa, the Middle East and India (23,24). Estimates of hunger risk based on assumptions about future population growth, international trade and agricultural technology have not yet factored in extreme weather events (24) or increases in agricultural pests and pathogens (25).

Human Migration

Through its adverse effect on the environment, population growth is a significant cause of the increase in the number of environmental refugees. The United Nations estimates that as a result of continuing migration, 65% of the world population, including 61% of the population in developing regions, will live in cities by the year 2025 (26). As cities grow, other environments shrink. This problem will be greatly inflated if global warming causes sea levels to rise, encroaching on vast areas of land. Population shifts could occur within a country, or as international or intercontinental fluxes. Such mass movements can potentially impede attempts to achieve stable human development. Unexpected human migration can stress unprepared health infrastructure especially in the face of a new illness native to the migrant population. Human migration has been a major source of epidemics throughout history resulting in spread of many diseases such as plague and smallpox.

Acute inhabitation disturbances lead to temporary living arrangements such as refugee camps and shelters, which provide ideal grounds for the emergence and spread of infections. The common factors inevitably surrounding temporary living arrangements are crowding, inadequate sanitation, limited access to medical care, deficient clean water and food, mixed strata population and inadequate and ineffective barriers from vectors and animals (27). Complex ecological interactions result from several factors working in unison or in tandem. Rural to urban migration can inject localized infection into a large vulnerable host population. Such health perturbations can be the last straw for the health infrastructure in overcrowded and rapidly growing cities, leading to a serious breakdown in public health measures and facilitating establishment of newly introduced infections (28).

Vector-Borne Diseases

Global climate change will affect disease vectors, which in turn may alter the current patterns of vector-borne diseases (29). The most common vectors, arthropods, are cold-blooded, meaning that their internal temperature is greatly

Table 2. Factors affecting arthropod-borne diseases

Vector factors	Host factors
Size of vector population	Size of host population
Proportion of vectors carrying disease	Susceptibility of existing hosts
Biting rate	Migration/creation of new susceptible hosts
Availability/requirement for intermediate host	Degree to which the host enters the vector environment
Ability of vector to survive the disease	Mortality rate caused by the disease
Lifespan/mortality rate of the vector	Potential for prolonged immunity
Efficiency of transmission of the disease via the arthropod bite	Availability/efficacy of vector control measures
Sustainability and renewal of infected vector population	Availability of disease control measures

affected by the temperature of their environment. The incidence of arthropod-borne diseases will depend on both vector and host factors (Table 2) (28). Climate may affect all of these factors to some extent but will have its most direct effect on the size of the vector population. Malaria, dengue, plague, and viruses causing encephalitic syndromes are among the many vector-borne diseases that may be affected.

The effect of global warming on malaria has been actively debated. In modern times, we tend to think of malaria as a tropical disease. However, malaria has existed in many temperate areas of the world (30). Outbreaks have occurred as far north as the Arctic Circle and the disease has flourished in much of Europe and North America. European visitors to the New World found malaria already firmly established. In Europe, cases of malaria persisted throughout the Little Ice Age, a period of intensely cold winters and cool summers that began in 1564 (30). The mosquito vectors that carried the parasite in these temperate climates still exist. Yet, malaria has almost vanished from developed countries. Clearly, the reason for the dramatic decrease in cases of malaria is not climatologic. Rather, the change is attributed to better mosquito control measures, and more effective antimalarials. Unfortunately, mosquitoes have become alarmingly resistant to control measures and drug-resistant malaria is spreading. Malaria cases have been on the rise (31). We cannot rely on the measure of the past to provide a safe haven for us in the future. Moreover, the lack of malaria in developed countries is sustained in part by the lack of infected human hosts. Mosquitoes rarely encounter an infected host and so rarely acquire the parasite. Will global warming reverse these trends?

The situation and the risk are most dire in developing countries. Malaria is currently concentrated in areas of poverty (32), with 90% of cases occurring in Africa. (33). Approximately 40% of the world's population lives in a malarious area (34). In Africa, there are 300–500 million cases of malaria annually, with 1.5–2.7 million deaths (33). Up to 90% of the African deaths occur in children under the age of 5 years. In contrast, about 1500 cases of malaria occur each year in the U.S., almost all of which are imported, with 0 to 12 deaths per year (35).

In many ways, our current inability to control malaria is a reflection of the uneven distribution of global public health resources. Control of malaria includes vector management and disease therapy. Vectors can be reduced through the use of insecticides that are applied to individuals or their environment. History has shown that mosquitoes can become tolerant to potent environmental insecticides and that some products will have unforeseen consequences for other wildlife. Personal measures may also be taken including using insect repellants, room sprays, and screens on windows. Impregnated bed netting has been shown to be an effective means of reducing malarial transmission. For the poor, especially in developing countries, the cost of these personal protective measures is often prohibitive (36).

Malaria control is extremely difficult. The oldest method of vector control—drainage—still remains the most cost effective particularly in areas with high population and low water resources (37). There are studies to show that simple measures such as irrigation control can control malaria spread (38,39). The progression of aquatic stages of development of the Anopheline vector is accelerated under conditions of increased temperature with optimal larval development at 28°C and optimal adult development between 28° and 32°C (40) Thus, global warming provides conditions conducive to the spread of malaria.

Malaria transmission is influenced by climate. Clearly, transmission does not occur in climates where mosquitoes cannot survive. Warm, moist climates are most conducive to mosquito propagation and survival. The breeding habitat of the *Anopheles* vector is water. Anopheles mosquitoes are found most commonly in deciduous and mixed forests as well as around human habitation (41). Mosquito larvae are found in small pools of water. Factors affecting larval breeding include quantity of food, density of larvae and salinity of the surrounding medium (42). The eggs are laid singly on the water surface film and can survive winter weather resiliently. The progression of aquatic stages of development of the Anopheline vector is accelerated under conditions of increased temperature with optimal larval development at 28°C and optimal adult development between 28° and 32°C (40). Malaria transmission cannot occur below 16°C or above 33°C as sporogony cannot occur. The ideal conditions for transmission are high humidity and environmental temperatures between 20° and 30°C. Rates of transmission also depend on the number of times the infected mosquito bites the host and the duration of the mosquito lifespan, both of which are influenced by temperature (37). Thus, global warming provides conditions conducive to the spread of malaria.

In holoendemic or hyperendemic areas, childhood mortality from malaria is high. Over time, the population develops premunition immunity that allows parasite inhabitation but protects against infection. This is not the case where malaria occurs seasonally, implying that spread of malaria to non-endemic or unexposed regions of the world as a consequence of climatic change can have severe impact on the vulnerable population. Human migration will also bring infected persons into contact with uninfected mosquitoes and subsequently will expose non-immune hosts to newly infected mosquitoes.

Deforestation, human migration and agricultural practices have a serious impact on malarial transmission. Urban malaria has become an increasing health concern in many countries (41). Crowding of humans in dwellings is associated with increased indoor mosquito concentrations (43). Humans, after all, are a source of food for mosquitoes.

Many global warming scenarios include an increase in the frequency and intensity of the El Niño phenomenon (44). The El Niño Southern Oscillation is heralded by warm water flowing off the coast of Peru and Ecuador. It is caused in part by pressure differences in the air over the Pacific Ocean. Although beginning in the Pacific, the climatic effects of El Niño are global. Storms, heavy rain, regional drought, and warm temperatures are more frequent during El Niño (45). El Niño seasons have been associated with outbreaks of malaria in many areas (46,47). However, the association is not constant and outbreaks have been regionally limited. It is important to point out that El Niño is a short-term climate change and that global warming implies a prolonged change. Thus, it is hazardous to extrapolate the effects of El Niño to predict the overall results of global climate change (48). However, El Niño events are predicted to become more common and more severe with global warming, and it appears likely that this will facilitate local epidemics of malaria.

From the standpoint of malaria, the effect of global warming will be felt most in areas that are currently on the edges of the range of infected mosquitoes (49). For example, malaria has been shown to march up mountains in response to wetter, warmer weather (50,51). Altitudes that were once safe from mosquitoes will be at risk for epidemics. Tanser and colleagues (33) developed a model to predict the effect of global warming on exposure to the mosquito vector for malaria in Africa. The model was based on the historical associate of rainfall and temperature readings from 1920 to 1980 in Africa. Population estimates were overlaid on top of regional temperatures and were assumed to remain constant. The model was validated using existing mosquito surveys. Three potential global warming scenarios were considered, based on estimates from the Intergovernmental Panel for Climate Change. In the scenarios, atmospheric carbon dioxide increased by 47, 98, and 126% by the year 2100. Using these estimates, the number of person-months of exposure to the mosquito vector increased by 16, 23, and 28% for each scenario, respectively. The increase was predominately attributable to vector exposure at higher altitudes than currently. Ethiopia, Zimbabwe and South Africa experienced the largest projected changes. There was little latitudinal spread into new territories.

Increasing precipitation is not always favorable for mosquitoes. Torrential rains may wash away breeding sites and drought may eliminate the small pools of water favored by the mosquitoes for their eggs. On the other hand, drought in very wet areas may slow rapid streams and create pools of stagnant water (45).

Global warming may also bring famine and drought, leaving populations more susceptible to disease. Early models to predict malaria rates in the 1920s were based on rainfall and prices of wheat (50). When food was scarce, the price of wheat increased, making price a surrogate for crop failure and malnutrition.

Finally, unforeseen factors may also influence malaria. The availability of an effective vaccine, better insecticides, or more effective antimalarials would each reduce the prevalence of the disease. Breakdowns in existing public health measures would increase cases of malaria. The balance between these factors may be more important than global climate (52).

Dengue is an important mosquito-borne disease affecting humans and is transmitted by *Aedes aegypti*. This mosquito is well adapted to the urban environment and successfully breeds in containers where water is allowed to accumulate, such as discarded cans, bottles, plastic containers and tires. *Aedes* mosquitoes thrive in warmer environments but not in dry environments. Thus, the effect of global warming on diseases like dengue depends on both precipitation and temperature (53,54). Vezzani et al. (55) studied the breeding of *Aedes* mosquitoes in Buenos Aires, Argentina. They noted highest abundances in breeding after several months with mean temperatures above 20°C and accumulated rainfalls above 150 mm. A sharp decline in egg laying was observed when monthly mean temperature declined to 16.5°C, and no eggs were found below 14.8°C. As with malaria, changes in the incidence of dengue appear strongly related to non-climatological factors. For example, there is a dramatic difference in the incidence of dengue along the Mexican−U.S. border. States south of the border have a 500-fold increased incidence of disease compared with those just north of the border (48). Thus, climate appears to be only one factor in transmission of the disease.

West Nile fever is another emerging viral infectious disease and is transmitted by *Culex* mosquito species. Its habitat is usually near swamps, ponds and other bodies of stagnant water, waterways, parks, golf courses, undeveloped wood lots, and temporary wetlands in densely populated residential areas (56). Although the life span of the mosquito diminishes with excessive temperatures, viral maturation rates increase with temperature. It has been suggested that, as a result of climate change, there could be a northward shift in western equine and St. Louis encephalitis, with the disappearance of the former in southern endemic regions (57).

Other vectors will be affected to different extents. Models to predict tick populations have also shown that arid conditions decrease tick populations. However, epidemics of tick-borne diseases such as Lyme disease have not been associated with climate change (58). As stated above, it is possible that global warming will bring stronger or more frequent El Niño events. This will be to the advantage of some vectors. In the strong El Niño of 1997–1998, there was an associated increase in Rift Valley Fever (51). The mosquito vector populations increase during times of flooding, because more eggs are immersed in water (59).

Vectors may transmit pathogens to non-human mammalian hosts. Indeed, for some diseases humans are an accidental host. Arboviral encephalitides, such as West Nile encephalitis, St. Louis encephalitis, and LaCrosse encephalitis, infect both human and non-human mammalian hosts (54). Other pathogens, such as *Borrelia burgdorferi*, the cause of Lyme disease, also utilize non-human mammalian hosts. Clearly, the effect of climate on the non-human host will affect human disease.

Rodent breeding increases during mild weather and decreases in times of drought or heat. However, drought may drive rodents to seek indoor sources of water. This increases the chances that humans will come in contact with rodents and the insects that feed on rodents, such as lice. Transmission of plague and similar diseases may increase with rodent populations. Moreover, the hantaviruses are spread through secretions or excretions of infected rodents.

In summary, vector-borne diseases will be affected by global climate change. Malaria is likely to spread locally, especially into altitudes that are adjacent to current endemic areas. However, for malaria to spread more widely in developed countries, it will be necessary for there to be a breakdown in public health measures that currently keep the disease at bay. Other arthropod-borne diseases are likely to fare similarly. Extreme climate change is not good for humans or vectors, and it is difficult to predict the results. Milder or more gradual climate change would allow both humans and vectors to adapt. Successful adaptation in humans might mean better vector control measures, more effective therapies, vaccines, or public health measures.

Discussion

Human infections are intricately linked to the global environment. By altering this environment, global warming has significant potential to intensify selected infectious diseases. Climatic effects are predicted to include crowding, famine, water contamination, human migration, and alterations in vector ecology, all of which increase infectious diseases. We have dealt with these problems in the past with varying success. Global warming will also cause economic strain that may divert public health resources from existing infections. Through planning and research, we can mitigate the health effects of global warming. Through policy, politics, and global cooperation, we may reduce the environmental problems that cause global warming.

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