

Preventing Disease Outbreaks: How the Debate Surrounding Climate Change's Influence on Mosquito-Borne Diseases Hampers Immediate Action

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Introduction

A mosquito is a slender, long-legged fly; however, this insect is the most deadly animal in the world. The term “mosquito” is misleading; it is Spanish for “little fly.” However, there is nothing “little” about the one million deaths worldwide that mosquitoes are responsible for annually (American Mosquito Control Association). Mosquitoes are disease vectors with the ability to carry and transmit viral diseases to other living organisms. They are responsible for the transmission of several dangerous diseases, such as malaria, West Nile virus, dengue fever, and Zika virus. Malaria is the most deadly of mosquito-borne diseases, killing one child every 40 seconds and affecting over half a billion people annually (American Mosquito Control Association). In hopes of developing preventative measures to control future mosquito-borne disease outbreaks, medical researchers have focused on identifying the primary factors that can accelerate the spread of such dangerous diseases. One possible, though controversial, factor is global climate change.

Medical researchers differ in their willingness to attribute climate change to the increased distribution of mosquito-borne diseases. While vector biologists tend to feel as though climate change's drastic increase in global temperatures is insignificant and overshadowed by a myriad of other human factors, more environmentally-minded medical researchers argue that climate change will increase the distribution of mosquitoes globally and thus increase the incidence of infectious diseases. An overwhelming majority of experts in the field of epidemiology believe that various socio-economic, demographic, and environmental factors are just as responsible as climate change in influencing the prevalence of mosquito-borne diseases. While each side of this debate supports their differing arguments through the use of statistics, predictive models, and past research, the purpose of the debate is obscured in the process.

Climate change's influence on mosquito-borne dis-

eases is of much discussion; however, the relationship between climate change and disease transmission will not alter the measures taken to control disease outbreaks because climate change is caused by the same human behaviors that medical researchers agree contribute to the spread of mosquito-borne diseases. As a result, rather than conducting long-term studies to better understand climate change's direct impact on mosquito-borne diseases, medical researchers should prioritize tackling human factors, such as deforestation, urbanization, and water control projects, that lead to both climate change and the increased prevalence of infectious diseases.

The Misunderstood Debate: Climate Change's Controversial Role

The lack of long term studies analyzing the relationship between climate change and disease dynamics causes researchers to rely on their unique disciplinary backgrounds and the differing temporal frameworks of their evidence in interpreting the significance of their similar observations. The various conclusions that medical researchers draw from seemingly objective facts shape the debate, but the divergence of these conclusions hinder immediate action.

Vector biologists, such as Paul Reiter, downplay climate change's influence on vector-borne diseases, believing that the behavioral factors of both humans and vectors have more direct ties to the incidence of infectious diseases. However, public health experts, such as Paul Epstein, an Associate Director of the Center for Health and the Global Environmental at Harvard Medical School, believe that altering climatic patterns pose favorable conditions for mosquitoes to carry and transmit infectious diseases. While Epstein and Reiter both acknowledge the expanded distribution of mosquito populations, Epstein is more likely than Reiter to attribute such an observation to climate change because of his background in public health. Epstein writes in his *Scientific American* journal entry, that “the case for a climatic contribution becomes stron-

ger...when other projected consequences of global warming appear in concert with disease outbreaks" (Epstein, 2000). This, he believes, is the case in highlands around the world, for "mosquitoes, once limited by temperature thresholds to low altitudes...are being reported at high elevations in South and Central America, Asia, and east and central Africa" (Epstein, 2000). These climate change indicators, however, are the same indicators that Paul Reiter exposes as deceptive in his most recent article, "Global warming and malaria: knowing the horse before hitching the cart."

Reiter, a medical entomologist and member of the World Health Organization Expert Advisory Committee on Vector Biology and Control, believes the reemergence of mosquito populations in many highland areas has more to do with the interaction between human behavior and mosquito biology than climate. According to Reiter, "Nairobi was well known for its malaria" and "had big problem with malaria... after World War I, when a lot of white people started settling in the Kenya highlands. [This problem] continued until the advent of DDT in the 1950s" (EIR, 2007). Reiter uses the history of human-host interactions in African countries as evidence to refute Epstein's argument that climate change is bringing about the introduction of mosquito-borne diseases in unexpected regions. As a public health researcher, Epstein uses current outlooks on climate change to predict how this global phenomenon will shape the future incidence of infectious diseases, unlike Reiter, who seems limited in his strict consideration of historical and entomological factors. However, an overwhelming majority of medical researchers find neither the arguments of Reiter nor Epstein rather convincing as a result of their narrow and exclusive viewpoints.

Most medical researchers acknowledge that arguments citing a causative relationship between climate change and the spread of mosquito-borne diseases are oversimplified because of their limited consideration of other confounding variables; in order to identify climate change's true implications on human health, these researchers believe historical and current trends must be considered through an epidemiological lens. In his article, "Early effects of climate change: do they include changes in vector-borne disease?," R.S. Kovats, a lecturer on environmental epidemiology at the London School of Hygiene and

Tropical Medicine, argues that "the observation that climate change is associated with changes in vectors or diseases does not, of itself, prove a causative relationship, since it is usually not possible to completely exclude all alternative explanations for any change in disease patterns" (Kovats, 2001). Confounding variables, which include globalization, land use, demographics, and human behavior, make it statistically erroneous to correlate mosquito-borne disease incidence directly to climate change; thus, Kovats believes climate change should be considered one of many factors influencing disease dynamics. Kovats argues that there is a lack of strong evidence of an impact of climate change on vector-borne diseases, further necessitating the need to conduct long-term studies analyzing the relationship between the two.

Although medical researchers have differing opinions regarding the impact of climate change on disease transmission, a majority agrees that there is a lack of concrete evidence to support a direct correlation between the two; such lack of evidence creates this debate. However, with medical researchers so heavily invested in such a passionate debate, the purpose of the debate is often buried within the argument itself and unclear at times. What is the purpose of researching the impact of climate change on the transmission of mosquito-borne diseases? Medical researchers believe scientific evidence of the relationship between the two will result in more effective preventative measures. However, the close relationship between climate change and other human-related factors, such as deforestation, urbanization, and water control projects, allows each of them to be treated as a single factor rather than multiple factors influencing mosquito-borne diseases. Thus, climate change's effect on the spread mosquito-borne diseases is inherent within the human-related factors themselves.

Outdated Solutions: The Concerning Outlook for Modern-Day Preventative Measures

By isolating factors that play a role in influencing the dynamics of mosquito-borne diseases, medical researchers hope to develop preventative measures that will more effectively target such specific factors, thus minimizing global disease emergence. To develop these measures, researchers must identify the factors that influence disease emergence and determine how

to control such factors. Through this research, modified mosquito and virus control procedures can be developed to allow for the long-term treatments necessary to aid patients and prevent such diseases. Identifying the role of climate change, however, would not help in the development of control measures because of the close association between climate change and human behaviors; climate change should be treated as inseparable from individual human factors because of their interdependence. Indeed, many past eradication efforts have had little to do with the changing climate, yet many solutions have allowed for a reduction in mosquito-borne infections over the past century. However, the changing dynamics of these diseases have allowed for their resurgences, further necessitating the development of alternative solutions targeting the individual human factors contributing to the increased prevalence of mosquito-borne diseases.

The history of control strategies aimed at reducing the burden of mosquito-borne diseases provides important insights into current control strategies. For the past 120 years that mosquitoes have been identified as vectors responsible for the transmittance of various infectious diseases, medical researchers have been exploring the effectiveness of various preventative measures that can be traced back to the 1940s.

The discovery of DDT and the establishment of the World Health Organization defined a period of optimism that lasted from the late 1940s to the mid-1960s. The prevention and control of mosquito-borne diseases, more specifically malaria, became a central focus. Researchers were hopeful that “time-limited special-purpose campaigns, involving DDT spraying, chloroquine chemotherapy and active case surveillance, [would] achieve global eradication in a matter of years” (World Health Organization, 1999). The trend in vector-borne diseases quickly flipped over the course of a few years. For example, malaria had been nearly eliminated in Sri Lanka, with only 31 and 17 cases reported in 1962 and 1963, respectively (Gubler, 2010). The dramatic decrease in cases of malaria caused many nations to be hopeful of having the ability to “banish malaria completely from their borders” (World Health Organization, 1999). However, by 1967, 3,468 cases of malaria were reported in Sri Lanka, followed by a major epidemic of 440,644 cases the next year (Gubler, 2010). Virus resistance

to DDT and concerns about its safety resulted in waning support for such control strategies, quickly dwindling early optimism surrounding the premature idea of eradicating mosquito-borne diseases.

Following limited international funding for malaria control in the 1970s and 1980s, a revised global strategy approved by the World Health Organization in 1992 resulted in a greater emphasis placed on the importance of malaria control. Through focused research on the containment and control of malarial epidemics, scientists were able to develop a wide range of tools for malaria prevention. An insecticide-treated net is an example of such a tool that has become an increasingly popular preventative measure over the past 15 years. While “the use of treated bednets and curtains has led to reductions in child mortality ranging from 14% to 63% in African trials,” implementation remains limited and achieving high retreatment rates of nets has proved to be difficult (World Health Organization, 1999). Moreover, the perfection of insecticide-treated nets is not a comprehensive solution to disease outbreaks. Other current preventative measures include the use of drugs, early treatment, and residual house spraying of insecticides. However, these control strategies are limited in their effectiveness because of the distinct challenges facing each one. Although the use of drugs is a simple and cost-effective way to manage infectious diseases, the regulation of drug vendors presents an even bigger issue. Although access to early treatment of diseased individuals reduces the rate of malarial infection, it is economically unfeasible for many individuals of low socioeconomic status living in developing countries to get the good quality treatment they so critically need. Although house spraying of insecticides allows for the management of mosquito populations, its potential environmental and health effects in conjunction with its creation of resistant mosquito and virus populations make it a poor option. While many of these control strategies may provide temporary relief, they by no means represent a panacea.

As a result of the numerous drawbacks of current interventions, research should be focused on the development of nuanced preventative measures that target the human activities contributing to changing disease dynamics but do not ignore the possible influence of global climate change. By analyzing each factor’s close

relationship to climate change, solutions can be tailored to address each human-related factor influential to the spread of mosquito-borne diseases while inherently curbing the severity of climate change as well.

The Relationship Between Human Behaviors and Climate Change

Most voices in the debate echo that there are various human-related factors contributing to the increased incidence and distribution of mosquito-borne diseases. Since “there are a number of other significant social and environmental drivers of vector-borne disease transmission in addition to climate change,” (USGCRP) it is difficult to assess the extent to which climate change affects disease transmission. However, the relationship between climate change and the prevalence of mosquito-borne diseases will not alter the measures taken to control disease outbreaks because climate change is caused by the same human behaviors that have already been identified by medical researchers to contribute to the spread of infectious diseases.

In considering the relationship between climate change and mosquito-borne diseases, medical researchers agree that human activities on a more local scale have noticeable impacts on the dynamics of disease. For example, Paul Reiter cites numerous human activities and cultural and behavioral traits that affect disease transmission. Forest clearance, infrastructure projects, urbanization, and higher birth rates are a few of many human-related factors that contribute to the creation of excellent breeding sites for mosquitoes and the expansion of their physical habitable ranges. However, these same factors contribute to the phenomenon of human-induced climate change as well.

While many developing countries are forced to clear forests for the agricultural demands of their growing populations, such forest clearance releases sizeable amounts of carbon dioxide into the atmosphere and thus increases global temperatures. According to the World Carfree Network, deforestation is responsible for 15% of global carbon emissions (Scheer, 2012). When trees are cut down, they release the carbon they once stored into the atmosphere, where it reacts with oxygen to form carbon dioxide. Carbon dioxide, a greenhouse gas, traps heat and warms the Earth’s surface. Deforestation is only increasing; according to the Environmental Defense Fund,

“Unless we change the present system that rewards forest destruction, forest clearing will put another 200 billion tons of carbon into the atmosphere in the coming decades” (Scheer, 2012). Global climate change will continue to worsen with increased rates of deforestation, and the incidence of mosquito-borne diseases should expect to increase as well.

Deforestation creates ideal conditions for mosquitoes to breed and spread their infectious diseases. For example, the epidemiology of malaria in the Amazon is being altered as “deforestation and land alteration facilitate environmental and climatic conditions that impact the ecology of mosquito habitats and create new places for water to accumulate” (Gottwalt, 2015). As a result, mosquitoes, which breed in undisturbed standing water, will have more area in which to breed, creating a larger mosquito population to spread the disease. Such altering ecosystem dynamics result in a strong, positive association between deforestation and the emergence of vector-borne diseases. Urbanization and population demographics, like deforestation, contribute to both climate change and the increased incidence of mosquito-borne diseases.

As the world’s population continues to expand and people are forced to settle in densely populated urban areas, the increased consumption of resources and use of fossil-fuels will contribute to the changing climate. Currently, the Earth has a human population of over 7.3 billion, according to the United Nations Department of Economics and Social Affairs. It is expected to reach nearly 10 billion people by 2050 (UN DESA, 2015). The continued population growth will force many to concentrate in urban areas as a result of the limited land available for such a rapidly growing population. In fact, globally, more than 54 percent of the world’s population resides in urban areas, and by 2050, 66 percent of the world’s population is expected to be urban (UN DESA, 2014). Climate change is largely influenced by this urban growth because “in order to keep up with rapid urban expansion and urban population growth, more resources as well as more consumption and production are required” (Sustainable Urban Futures, 2016). Since most of the “primary energy sources transformed to be available to most of the cities around the world are still fossil-based,” cities are responsible for more than 75% of greenhouse gas emissions, a trend that will intensify with

an increasing population (Sustainable Urban Futures, 2016). In addition to contributing to climate change, increasing urban populations result in a greater prevalence and distribution of mosquito-borne diseases.

Urbanization and changing population demographics increase the potential for mosquito-borne disease outbreaks by providing mosquitoes with human “hosts” to prey on. Nikhita Puthuveetil of the Virginia Commonwealth University argues that while “urbanization often destroys the habitat of the virus and its vector,” mosquito-borne viruses and their vectors are highly adaptable (Puthuveetil, 2016). Due to urbanization and an increase in the number of humans, some mosquito species become anthrophilic, preying specifically on humans rather than animals. Thus, urbanization often promotes both mosquito population growth and virus population growth. Likewise, urbanization and a growing population promote a greater need for resources. Water is an example of a resource that is vital for a growing population. Many urban cities rely on canals and dams for the transportation and storage of water. However, like urbanization itself, these water control projects contribute to climate change and the fluctuating dynamics of mosquito-borne diseases.

While small-scale water projects are meant to better society through the creation of infrastructure that will provide for local communities, they have become one of the largest sources of greenhouse gas emissions. Although water control projects, such as the creation of reservoirs, irrigation canals, and dams, are necessary for the transportation and storage of water in many communities around the world, these seemingly “small” water projects are major sources of climate-changing pollution. For example, according to Brazil’s National Institute of Space Research (INPE), “dams may be one of the single most important contributors to global warming, releasing 104 million metric tons of methane each year” (International Rivers, 2007). Thus, Ivan Lima and his colleagues from INPE imply that the world’s 52,000 large dams contribute more than 4% of the total warming impact of human activities and are the largest single source of human caused methane emissions. These infrastructure projects similarly contribute to the increased prevalence of infectious diseases.

Water control projects also expand the distribution of mosquito-borne diseases by providing breeding sites for mosquitoes. For example, “in the tropics, during construction of dams and canals, excavation pits provide breeding sites for mosquitoes where they lay buoyant egg masses” (Patz, 2000). Moreover, deeply shaded pools, seepages in forests, footprints, irrigation ditches, and excavated depressions in the open sunlight add to the possible areas mosquitoes can deposit their eggs. Water control projects provide plentiful habitats for mosquitoes to breed and thrive. Such a “wide variety of conditions under which at least a few species [of mosquitoes] are able to thrive ensures that parasitic disease is ubiquitous [and] flourishing throughout many regions of the world” (Patz, 2000). Deforestation, urbanization, and water control projects all promote the growth of infectious diseases by providing advantageous breeding sites for disease vectors. The interrelatedness of these human factors and climate change makes treating climate change as a separate influence to mosquito-borne diseases unnecessary.

Umbrella Solutions: Climate Change’s Dependence on Local Human Activities

While there is no single panacea to the potential outbreaks of mosquito-borne diseases, control strategies that directly address the influences of such human activities on disease dynamics will better prevent infections than a debate about the role of climate change. Climate change itself may alter the dynamics of mosquito-borne diseases; however, control strategies focused on addressing human interactions and activities will inherently account for climate change’s possible influence on mosquito-borne diseases. Thus, in prioritizing the development of preventative treatments that target specific contributing factors to infectious disease over research on climate change’s possible influence, medical researchers will better be able to limit disease transmission.

Integrated vector management (IVM) can reduce vector breeding grounds altogether through improved strategy design. Unlike popular preventative measures today, IVM does not rely on a single method of vector control. Rather, it “stresses the importance of first understanding the local vector ecology and local patterns of disease transmission, and then choosing

the appropriate vector control tools, from the range of options available" (World Health Organization). IVM requires health impact assessments of new infrastructure development, which includes water resources, irrigation and agriculture; such assessments will help researchers "identify potential impacts on vector-borne disease upstream of major policy decision so effective action may be taken" (World Health Organization). IVM's environmental management strategies reduce vector breeding grounds through improved design and operation of water resources development projects and the use biological controls to target and kill mosquito larvae without generating the ecological impacts of chemical use. Thus, IVM is able to account for the local human activities that contribute to disease outbreaks. Like IVM, Integrated Pest Management focuses on seeking out control tactics customized for the factors influencing the prevalence of mosquito-borne diseases.

Integrated Pest Management's (IPM) emphasis on habitat management and control of the immature stages of mosquito species reduces mosquito populations while minimizing the environmental impact of mosquito control measures. IPM can be described as "an ecologically based strategy that relies heavily on natural mortality factors and seeks out control tactics that are compatible with or disrupt these factors as little as possible" (Environmental Protection Agency). Similar to IVM, IPM considers the interaction between control practices, weather, and habitat biology before deciding on a course of action. Control strategies, such as IVM and IPM, will reduce the prevalence of mosquito-borne diseases through various mosquito control techniques that simultaneously limit adverse health and environmental effects.

Conclusion

While recognizing factors influential to the spread of mosquito-borne diseases is helpful in developing control strategies, medical researchers seem to sacrifice the development of preventative measures in order to focus on identifying the possible influence of climate change on vector-borne diseases. Medical researchers argue for the necessity of additional long-term research analyzing the correlation between climate change and mosquito-borne diseases in hopes of thus being able to tailor control strategies to tar-

get the influence climate change has. However, such time and resources are better spent creating more effective control strategies for mosquito-borne diseases because of the close association between climate change and other human factors. These interventions will inherently account for climate change's possible influence due to the strong correlation between the human actions responsible for disease transmission and climate change itself. Innovative control techniques will prove to be necessary in order to prevent and treat infectious disease outbreaks; however, to be of maximum effectiveness, individuals must learn to abstain from partaking in the activities promoting the spread of disease in the first place.

In order to prevent the spread of mosquito-borne diseases and the incidence of climate change in the first place, public education can serve as a powerful tool. Through public education, individuals can limit their carbon footprint and thus limit their influence on the spread of mosquito-borne diseases. There are many ways for ordinary individuals to limit their contributions to both global climate change and the spread of mosquito-borne diseases. For example, through recycling, going paperless, and eating vegetarian meals as often as possible, individuals will lessen the need for deforestation, thus reducing vector-breeding sites and the amount of greenhouse gases contributing to global climate change. Individual actions can be taken to address each human-related factor contributing to disease outbreaks.

Medical researchers must focus on developing improved preventative measures to control the resurging mosquito populations responsible for spreading infectious diseases. When considering the global phenomenon of climate change and the biology of a mosquito, the importance of the two in this debate is obscured because of their relative sizes. Medical researchers focus on the process of climate change in hopes of preventing future disease outbreaks, but they should be more focused on how certain human activities affect the prevalence of disease-carrying mosquitoes. Once again, the deceiving size of a mosquito masks the potent capabilities of the "little fly."

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