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Editorial: Climate Change and the Spread of Vector-Borne Diseases, Including Dengue, Malaria, Lyme Disease, and West Nile Virus Infection

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Abstract The major health threats from climate change include increasing temperatures, air pollution, extreme weather events, changes in the spread of infectious diseases, antimicrobial resistance, emerging pathogens, and an increase in vector-borne disease. Between October and December 2023, in 200 medical journal, epidemiologists, clinicians, healthcare policymakers, and journal editors published an emergency call to action to health professionals, the United Nations, and political leaders on climate change and its effects on the ecosystem and human health. Also, in December 2023, the Intergovernmental Panel on Climate Change (IPCC) published its sixth Assessment Report (AR6) that summarizes current knowledge, impacts, and health risks from climate change, as well as suggestions for mitigation and adaptation. For over a decade, the IPCC has reported that the prevalence of vector-borne diseases has increased and highlighted the importance of monitoring dengue, malaria, Lyme disease, West Nile virus infection, and other vector-borne diseases. This editorial aims to provide an update on the association between climate change and the spread of vector-borne diseases and highlights the urgent need for public health and disease prevention and treatment strategies to control the rise in vector-borne diseases.

Keywords: **Climate Change • Dengue • Malaria • Lyme Disease • West Nile Virus • Editorial**

The primary health threats from climate change include increasing temperatures, air pollution, extreme weather events, changes in the spread of infectious diseases, antimicrobial resistance, emerging pathogens, and an increase in vector-borne disease [1-3]. In 2021, at the height of the COVID-19 pandemic, Atwoli and colleagues, writing in the British Medical Journal (BMJ), highlighted that climate and biodiversity should be regarded as components of the same complex problem resulting in damage to the environment, and all life on earth, with increasing impacts on human health, due to the effects on food supplies, water supplies, the effects of temperature, and the spread of disease [4]. Also, in 2021, the European Academies' Science Advisory Council (EASAC) presented evidence that climate change is now predicted to overtake land-use change, including deforestation, as the primary driver of change and biodiversity loss [5]. This rapid change in biodiversity and distribution will affect all life forms, including plants, mammals, birds, arthropods, and mites, and the development and transmission of infectious diseases [5,6]. Studies on the effects of increased urbanization and urban land expansion have predicted an immediate effect on 855 species, either from species loss or change in habitat [6].

Between October and December 2023, epidemiologists, clinicians, healthcare policymakers, and journal editors have published an emergency call to action to health professionals, the United Nations, and political leaders on climate change and its effects on ecosystems and human health [7,8]. This article has now been published in more than 200 international journals, which are listed online [8]. It is time to recognize that climate change and loss in biodiversity are a single crisis and must be addressed together to preserve human health, avoid health emergencies, and control vector-borne human disease [7]. In December 2023, the 28th United Nations Climate Change Conference of the Parties (COP) was held in Dubai, but it is unclear whether the immediate effects on vector-borne diseases from rapidly changing ecosystems were considered [7,8].

Also, in December 2023, the Intergovernmental Panel on Climate Change (IPCC) published its sixth Assessment Report (AR6) for policymakers that summarizes current knowledge, impacts, risks of climate change, as well as suggestions for mitigation and adaptation [9]. The 2023 IPCC report has also recognized the interdependence of climate, biodiversity, ecosystems, and human societies and the close associations between climate change

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adaptation, mitigation, ecosystem and human health, and sustainable development [9].

During 2023, there have been reassurances that the COVID-19 pandemic is now at an end, and vaccination programs for SARS-CoV-2 have shown global success in terms of reducing mortality from COVID-19, even though new SARS-CoV-2 variants continue to emerge [10]. However, this year, there have been increasing reports of changes in the geographical distribution of vector-borne diseases, highlighted by travelers and infectious disease surveillance programs [3,11]. Global warming is now affecting the behavior, distribution, and life cycle of vectors, including arthropods and mites, and also, the reservoir hosts and definitive hosts could increase the risk of spreading human-to-human disease [3,11]. Temperature directly affects the physiological traits of pathogens, vectors, and reservoir hosts and determines the rate of disease spread in susceptible populations [12]. Depending on the ability of vectors such as arthropods and mites to adapt, they may carry and transmit new pathogens as ecosystem changes bring pathogens, vectors, reservoirs, and human hosts closer together [12].

For over a decade, the IPCC has reported that the prevalence of vector-borne diseases has increased and highlighted the importance of monitoring dengue, malaria, Lyme disease, and West Nile virus infection [9]. The IPCC also predicts that these four major vector-borne diseases will increase in the next decades unless measures are taken to control climate change and vector-borne disease [9]. Notably, during 2023, there have been increasing reports of changes in the spread and incidence of dengue, malaria, Lyme disease, and West Nile virus infection.

Dengue is the most common mosquito-borne viral disease, reported in more than 100 countries, with 390 million annual cases [13]. There has been a steady increase in reports of dengue due to increased international travel and a decline in vector-control programs [14,15]. Humans are the main reservoir of four dengue virus serotypes [14,16,17]. Dengue is transmitted between humans by infected female mosquitoes, *Aedes aegypti* and *Aedes albopictus*, which breed in stagnant water [14,16,17]. Several factors have driven the northwest global expansion of dengue in the past decade, but the main cause of the expansion of these vectors is climate change [13,15]. In October 2023, more than 4.2 million cases of dengue (breakbone fever) were reported, compared with half a million in 2000 [18]. Although this disease was previously confined to the tropics, travelers in southern Europe also reported becoming infected [18]. Therefore, in addition to climate control and control of the vector, there is an increasing need to develop effective vaccines and treatments for dengue, as currently approved vaccines and treatments still have limitations [19].

Malaria is transmitted between humans by infected female *Anopheles* mosquitoes and is currently the deadliest and most studied climate-sensitive vector-borne disease, with high rates of mortality in pregnant women and young children, mainly in Africa [16]. Recent developments and approvals for two malaria vaccines, RTS,S/AS01 and R21/Matrix M, have brought hope for preventing this mosquito-borne disease, which affects millions of people, mainly children [20]. However, on November 30, 2023, the World Health Organization (WHO) reported that the fight against malaria still faces serious challenges, as cases rose by up to 5 million in 2022, which has exceeded global targets to contain transmission [17]. In 2022, there were an estimated 249 million cases of malaria, with 58.4 cases per 1,000 people who are at risk, compared with the WHO target of 26.2 cases per 1,000 by 2025, which means that progress towards the 2025 milestone is off course by 55% and is predicted to be missed by 89% this year [17]. Challenges to reducing the incidence of malaria have included disruptions to healthcare caused by the COVID-19 pandemic, drug and insecticide resistance, conflict, and extreme weather events due to climate change [17]. Malaria cases increased most dramatically in areas where weather conditions were most extreme [17].

Climate change has also affected diseases transmitted to humans by ticks and mites [21]. Lyme disease, caused by the *Borrelia burgdorferi sensu lato* complex, remains the most common tick-borne disease worldwide [22,23]. In 2022, the estimated seroprevalence was 14.5% in the temperate regions of central and western Europe and East Asia [23]. Untreated Lyme disease is a multisystem chronic and debilitating disease [22]. Four dominant tick species exist, including *Ixodes scapularis* and *Ixodes pacificus* in North America and *Ixodes ricinus* and *Ixodes persulcatus* in Europe, with a wide range of reservoir hosts that include mammals and birds [23]. The life cycle and prevalence of tick vectors are determined by the abundance of reservoir hosts and the ambient air temperature [21]. In the US, the increases in cases of Lyme disease in the Northeast have been associated with increased white-tailed deer populations and climate change-associated human–tick interactions due to the extended summer season [23]. Also, warming temperatures have resulted in an expansion of *Ixodes* ticks into Norway and Canada, which have reported a recent increase in cases of Lyme disease [23].

West Nile virus is a neurotropic virus, first described in 1937 in Uganda [24]. West Nile virus is a member of the Japanese encephalitis serocomplex with a primary host in birds and is maintained in a bird-mosquito-bird cycle [24]. This virus is transmitted mainly by the *Culex* spp. mosquito [24]. Pigs have been identified as amplifying hosts, with humans and horses as incidental hosts [24]. West Nile virus was first identified in the US in 1999, with one case in New York City, and is now the leading cause of mosquito-borne disease in the US, with

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up to 7 million reported cases between 1999 and 2016 [25]. There have been reports of transmissions in transfused blood and transplanted organs [24]. Modeling studies have shown that an air temperature of 24°C or more results in a peak incidence of infection [26]. Cases of West Nile virus infections in North America and Europe were more common during the summer and autumn [24,27]. However, climate change has increased infection incidence and geographical expansion [24,27]. In the summer of 2022, increased cases of West Nile virus infections were reported in Mediterranean countries and northern European countries, associated with increased temperatures [27].

Conclusions

For over a decade, the IPCC predicted four vector-borne infections, dengue, malaria, Lyme disease, and West Nile virus infection, would become more widespread with global warming [9]. As climate change continues, there is a critical need for public health and disease prevention and treatment strategies to control these and other vector-borne diseases [9,28]. People in less developed countries suffer the most from vector-borne diseases. Therefore, public health initiatives to prevent vector-borne disease transmission and socioeconomic inequalities, including nutrition, housing, education, and access to healthcare, which are linked to health inequities, should be urgently addressed [4,7].

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