# The impact of climate change on the ecology and transmission of vector-borne diseases

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# Abstract

This book chapter focuses on the impact of climate change on the ecology and transmission of vector-borne diseases. Vector-borne diseases are transmitted by arthropods such as mosquitoes, ticks, and fleas, and climate change is expected to have significant impacts on the distribution and prevalence of these diseases. The chapter begins with an introduction to climate change and vector-borne diseases, and discusses the ways in which climate change is expected to impact the ecology of these diseases. It then examines the role of temperature and precipitation in the transmission of vector-borne diseases, and how climate change is likely to affect the geographic range of these diseases. The chapter also considers changes in vector behavior due to climate change, and how this will impact vector control measures. Case studies are presented to illustrate the impact of climate change on specific vector-borne diseases. The chapter concludes by discussing the public health implications of these changes and the policy responses that are needed to address them. Finally, future directions for research on the impact of climate change on vector-borne diseases are suggested.

Keywords: Climate,vector,disease,pathogens,insects,behaviour

# Introduction to climate change and vector-borne diseases

Climate change is one of the most significant challenges facing the world today. Rising global temperatures, changes in precipitation patterns, and extreme weather events are already having significant impacts on human health, ecosystems, and the global economy. One of the areas that is likely to be affected by climate change is the transmission of vector-borne diseases. Vector-borne diseases are infectious diseases that are transmitted by arthropods such as mosquitoes, ticks, and fleas. Examples of vector-borne diseases include malaria, dengue fever, Lyme disease, and Zika virus. These diseases already pose a significant burden on human health, and climate change is expected to make this burden even greater. Vector-borne diseases are a major public health concern, particularly in low- and middle-income countries where access to healthcare and effective disease control measures may be limited. The World Health Organization estimates that vector-borne diseases account for more than 17% of all infectious diseases, causing more than 700,000 deaths each year. Climate change is expected to exacerbate the burden of these diseases by altering the distribution and abundance of the vectors that transmit them, as well as the transmission dynamics of the pathogens they carry.

One of the primary ways that climate change is expected to impact vector-borne diseases is through changes in temperature and precipitation patterns. Changes in temperature can affect the development and survival of both vectors and pathogens, as well as the behavior of both hosts and vectors. Warmer temperatures can increase the reproduction rates and survival of mosquitoes, for example, which can lead to higher transmission rates of diseases like dengue and malaria. Changes in precipitation patterns can also have a significant impact on vector-borne diseases, as they can affect the availability of breeding sites for vectors and the survival of pathogens in the environment.

Another way that climate change is likely to impact vector-borne diseases is through changes in the geographic range of both vectors and pathogens. As temperatures rise, the geographic range of some vectors may expand, allowing them to move into new areas where they were not previously present. This, in turn, can lead to the emergence of new diseases or the reemergence of diseases that were previously under control. At the same time, some areas may become less suitable for vectors as temperatures and precipitation patterns change, leading to a contraction of the geographic range of some diseases.

The impact of climate change on vector-borne diseases is complex and multifaceted, and it poses significant challenges for public health and policy. However, by understanding the ways in which climate change is likely to impact these diseases, and by developing effective strategies to mitigate and adapt to these impacts, it may be possible to reduce the burden of vector-borne diseases in a changing climate. This chapter will explore the impact of climate change on the ecology and transmission of vector-borne diseases, and the implications of these changes for public health and policy.

# Climate change impacts on the ecology of vector-borne diseases

Climate change is expected to have significant impacts on the ecology of vector-borne diseases, including changes in the distribution and abundance of vectors, alterations in the behavior of both vectors and hosts, and changes in the transmission dynamics of pathogens (Harvell et al., 2019). For example, rising temperatures can increase the rate of mosquito reproduction and reduce the duration of the extrinsic incubation period for pathogens, leading to higher transmission rates of diseases such as dengue fever, malaria, and Zika virus (Mordecai et al., 2019). Changes in precipitation patterns can also affect the ecology of vector-borne diseases by altering the availability of breeding sites for vectors and the survival of pathogens in the environment (Kilpatrick, 2011).

The impacts of climate change on the ecology of vector-borne diseases are complex and vary depending on the specific disease and the region in which it is found. However, it is clear that climate change is likely to have significant consequences for the distribution, prevalence, and transmission of vector-borne diseases (Campbell-Lendrum et al., 2015). Understanding these impacts is essential for developing effective strategies for disease control and prevention in a changing climate.

Climate change can also have significant effects on the behavior and immunity of hosts, which can in turn affect the transmission of vector-borne diseases (Harvell et al., 2019). For example, rising temperatures can affect the behavior of hosts, such as birds and rodents, which can alter their interaction with vectors and the transmission of diseases (Ezenwa et al., 2016). Changes in precipitation patterns can also affect the survival of hosts and their immunity to diseases, potentially making them more susceptible to infection (Kilpatrick, 2011).

In addition, climate change can also affect the interactions between hosts and vectors, such as altering the timing of host and vector activity or changing the composition of host communities (Eisen & Eisen, 2018). These changes can have significant implications for disease transmission dynamics, including the emergence of new diseases or changes in the prevalence and severity of existing diseases (Campbell-Lendrum et al., 2015).

Understanding the effects of climate change on host behavior and immunity is important for developing effective strategies for disease control and prevention in a changing climate. This includes strategies that focus on reducing host susceptibility to disease, such as vaccination or other immune-boosting measures, as well as those that target the interaction between hosts and vectors, such as habitat management or other conservation efforts (Ezenwa et al., 2016).

# The role of temperature and precipitation in the transmission of vector-borne diseases

Temperature and precipitation are key environmental factors that influence the transmission dynamics of vector-borne diseases (Lafferty, 2009). Changes in temperature and precipitation patterns resulting from climate change can have profound effects on the distribution, abundance, and behavior of vectors, as well as the susceptibility and distribution of host populations (Liu-Helmersson et al., 2016).

Temperature has been shown to have a direct effect on the survival, reproduction, and development of vectors, with higher temperatures generally resulting in increased rates of reproduction and shorter incubation periods for pathogens (Kilpatrick, 2011). For example, higher temperatures can increase the biting rates of mosquitoes, leading to higher transmission rates of diseases such as dengue fever and malaria (Lafferty, 2009).

Precipitation can also have a significant impact on vector-borne disease transmission, particularly in regions where rainfall is a limiting factor for vector abundance and survival (Kilpatrick, 2011). Heavy rainfall events can lead to the creation of breeding sites for mosquitoes and other vectors, increasing their abundance and potentially leading to outbreaks of diseases such as West Nile virus and Rift Valley fever (Liu-Helmersson et al., 2016).

The effects of temperature and precipitation on vector-borne disease transmission are complex and can vary depending on the specific disease and the geographic region in question (Kilpatrick, 2011). Nonetheless, it is clear that climate change is likely to have significant impacts on the transmission of vector-borne diseases in many parts of the world, particularly in areas where vectors and hosts are particularly sensitive to changes in temperature and precipitation (Eisen & Eisen, 2018).

Understanding the ways in which temperature and precipitation affect the transmission dynamics of vector-borne diseases is crucial for developing effective strategies for disease prevention and control in a changing climate. This includes strategies that aim to reduce vector abundance and limit exposure of human and animal populations to disease, as well as those that focus on improving the resilience of host populations to disease (Kilpatrick, 2011).

# Climate change impacts on the geographic range of vector-borne diseases

Climate change is expected to lead to significant changes in the geographic range and distribution of many vector-borne diseases (Ostfeld & Keesing, 2012). As temperatures warm, the ranges of many vectors are likely to expand, potentially leading to the emergence of diseases in regions where they were previously absent (Weaver & Reisen, 2010).

For example, the range of the tick that transmits Lyme disease is expected to shift northward in response to warming temperatures, potentially leading to increased incidence of the disease in areas where it was previously rare (Ostfeld & Keesing, 2012). Similarly, the range of mosquitoes that transmit dengue fever and other diseases is expected to expand as temperatures warm, potentially leading to the emergence of new outbreaks in previously unaffected areas (Weaver & Reisen, 2010).

In addition to changes in the geographic range of vectors, climate change can also lead to changes in the distribution and abundance of host populations, which can in turn affect disease transmission dynamics (Randolph & Dobson, 2012). For example, changes in precipitation patterns can lead to changes in vegetation cover and habitat suitability for host populations, potentially altering disease transmission dynamics (Randolph & Dobson, 2012).

The impacts of climate change on the geographic range of vector-borne diseases are complex and can vary depending on the specific disease and the geographic region in question (Ostfeld & Keesing, 2012). Nonetheless, it is clear that climate change is likely to have significant impacts on the emergence and spread of vector-borne diseases in many parts of the world, particularly in areas where vectors and hosts are particularly sensitive to changes in temperature and precipitation (Weaver & Reisen, 2010).

Understanding the ways in which climate change is likely to affect the geographic range and distribution of vector-borne diseases is crucial for developing effective strategies for disease prevention and control in a changing climate. This includes strategies that aim to reduce vector abundance and limit exposure of human and animal populations to disease, as well as those that focus on improving the resilience of host populations to disease (Randolph & Dobson, 2012).

# Changes in vector behaviour due to climate change

Climate change can also lead to changes in the behavior of vectors, affecting their interaction with hosts and the transmission of diseases. Changes in temperature and humidity can affect the physiology and metabolism of vectors, altering their feeding patterns, survival, and reproduction (Parham & Michael, 2010). For example, warmer temperatures can increase the activity and biting rates of mosquitoes, while decreasing their incubation periods, leading to higher transmission rates of diseases such as dengue and malaria (Liu-Helmersson et al., 2014).

Climate change can also affect the seasonal timing and distribution of vectors and their hosts, leading to changes in the timing and intensity of disease transmission. For example, earlier onset of spring and warmer temperatures have been associated with earlier emergence and longer activity periods of ticks, leading to increased risk of tick-borne diseases (Ostfeld et al., 2018). Furthermore, changes in land use and other environmental factors associated with climate change can also affect vector behavior and disease transmission. For example, deforestation and urbanization can alter the habitat and distribution of vectors and their hosts, while changes in water availability can affect the breeding sites of mosquitoes and other vectors (Parham & Michael, 2010).

Understanding the complex interactions between climate change and vector behavior is crucial for developing effective strategies for disease prevention and control. In addition, new technologies such as remote sensing and ecological modeling can help to identify areas at risk of disease transmission and to monitor changes in vector behavior over time (Campbell-Lendrum et al., 2015). In addition to the factors mentioned above, climate change can also affect the genetic makeup and adaptation of vectors. Research has shown that changes in temperature and other environmental factors can lead to genetic mutations and changes in the expression of genes related to vector competence (Bargielowski et al., 2013; Glunt et al., 2015). These changes can affect the ability of vectors to transmit diseases and may even lead to the emergence of new vector species or strains with different transmission dynamics.

Furthermore, the interactions between vectors, hosts, and pathogens are complex and can be influenced by multiple factors, including climate, land use, and human behavior. For example, changes in agricultural practices, such as the use of irrigation, can create new breeding sites for mosquitoes and other vectors (Parham & Michael, 2010). Similarly, urbanization can create new habitats for vectors and increase human exposure to vector-borne diseases (Campbell-Lendrum et al., 2015).

Overall, the impacts of climate change on vector-borne diseases are complex and multifaceted, and their full extent and implications are still not fully understood. However, it is clear that climate change is an important factor that must be considered in efforts to control and prevent the spread of vector-borne diseases.

# Effects of climate change on vector control measures

Vector control measures, such as insecticide-treated bed nets, indoor residual spraying, and larviciding, have been effective in reducing the burden of vector-borne diseases in many parts of the world (WHO, 2021). However, the effectiveness of these measures can be influenced by environmental factors, including climate change. For example, changes in temperature and precipitation can affect the efficacy of insecticides and the survival and behavior of vectors, which can in turn impact the effectiveness of vector control interventions (Patz et al., 2010; Ogoma et al., 2014).

In addition, climate change can affect the implementation and sustainability of vector control measures. For instance, extreme weather events such as floods and droughts can disrupt the supply chain for insecticides and other control tools, and can also affect the capacity of health systems to respond to vector-borne disease outbreaks (Campbell-Lendrum et al., 2015). Climate change can also lead to changes in human behavior, such as increased outdoor activity or changes in land use patterns, that can affect exposure to vectors and the effectiveness of vector control interventions (Vezzani & Carbajo, 2008).

To address the challenges posed by climate change, vector control programs need to be flexible, adaptive, and integrated with broader health and development initiatives. This may involve the development of new tools and approaches that are tailored to local conditions and the changing distribution and behavior of vectors (WHO, 2021). It may also require greater collaboration and coordination between public health agencies, environmental agencies, and other stakeholders to address the complex and multidisciplinary nature of the problem.

# Case studies on the impact of climate change on vector-borne diseases

There have been several case studies that illustrate the impact of climate change on the transmission of vector-borne diseases. Here are a few examples:

1. Dengue fever in South America Dengue fever is a mosquito-borne disease that is widespread in South America. In recent years, there has been an increase in the incidence of dengue fever in the region, which has been linked to climate change. Rising temperatures and changes in precipitation patterns have led to an expansion in the geographic range of the Aedes aegypti mosquito, the primary vector for dengue fever, and increased the length of the mosquito breeding season (Morin et al., 2013).
2. Malaria in East Africa Malaria is a major public health problem in East Africa, where it is transmitted by the Anopheles mosquito. In recent years, there has been a shift in the geographic distribution of malaria in the region, with an increase in cases at higher altitudes. This has been linked to rising temperatures, which have enabled the Anopheles mosquito to survive at higher altitudes than previously thought possible (Lindsay et al., 2016).
3. Lyme disease in North America Lyme disease is a tick-borne disease that is endemic in parts of North America. In recent years, there has been an increase in the incidence of Lyme disease in the region, which has been linked to climate change. Rising temperatures have led to an expansion in the geographic range of the tick vector, Ixodes scapularis, and an increase in the length of the tick season (Ostfeld et al., 2018).

These case studies demonstrate the complex relationship between climate change and the transmission of vector-borne diseases. While climate change is not the only factor influencing the transmission of these diseases, it is an important driver that must be taken into account when developing strategies for disease control and prevention.

# Public health implications and policy responses to the impact of climate change on vector-borne diseases

The impact of climate change on the transmission of vector-borne diseases has significant public health implications. As the distribution and seasonality of these diseases change, new populations may become exposed, leading to outbreaks and increased morbidity and mortality. In addition, vector control measures may become less effective as the behavior and range of vectors change, making it more difficult to control disease transmission.

To address these challenges, policymakers and public health officials must take a comprehensive approach that considers the complex relationships between climate, the environment, vectors, and disease transmission. This may involve developing new surveillance systems and modeling tools to monitor and predict changes in disease transmission patterns, as well as implementing targeted vector control measures, such as insecticide-treated bed nets and larvicide treatments.

In addition, efforts to mitigate the impacts of climate change through reducing greenhouse gas emissions and adapting to changing climate conditions may also have important implications for vector-borne disease control. For example, improving water management practices and investing in climate-resilient infrastructure can help reduce mosquito breeding sites and limit the spread of water-borne diseases.

Finally, it is important to address the social and economic factors that contribute to the vulnerability of populations to vector-borne diseases. This may include improving access to healthcare and implementing community-based interventions that engage local communities in disease control efforts.

Overall, addressing the impact of climate change on vector-borne diseases requires a multi-faceted approach that considers the complex interactions between environmental, social, and economic factors. By taking proactive steps to mitigate the impacts of climate change and improve disease control measures, we can work to reduce the burden of vector-borne diseases and protect public health. In addition to the policy responses mentioned above, there are also international efforts underway to address the impact of climate change on vector-borne diseases. For example, the World Health Organization (WHO) has established a Global Vector Control Response framework, which aims to strengthen vector control programs and build capacity for surveillance and control of vector-borne diseases in low- and middle-income countries.

Furthermore, international collaborations and partnerships are essential to effectively address the complex challenges posed by vector-borne diseases and climate change. For example, the US Centers for Disease Control and Prevention (CDC) partners with organizations such as WHO and the Pan American Health Organization to provide technical assistance and capacity building to countries to enhance their vector control and disease surveillance efforts.

Finally, public education and awareness campaigns can also play a critical role in mitigating the impact of climate change on vector-borne diseases. These campaigns can help to increase awareness of the risks posed by vector-borne diseases, and provide information on how individuals can protect themselves and their communities from disease transmission.

# Future directions for research on the impact of climate change on vector-borne diseases.

While significant progress has been made in understanding the impact of climate change on vector-borne diseases, there are still many unanswered questions and areas for future research. Some key directions for future research include:

1. The impact of extreme weather events: While many studies have focused on the gradual changes in temperature and precipitation patterns, there is a need to better understand the impact of extreme weather events such as floods and droughts on the transmission of vector-borne diseases.
2. The role of host ecology: Many vector-borne diseases have complex life cycles that involve multiple hosts. Future research should aim to better understand the interactions between hosts and vectors, and how changes in host ecology due to climate change may impact disease transmission.
3. The impact of land use change: Land use change, such as deforestation and urbanization, can alter the habitat and distribution of vectors, as well as human behaviors that increase exposure to vectors. Future research should examine the impact of land use change on the distribution and transmission of vector-borne diseases.
4. The impact of interventions: While many interventions have been developed to control and prevent vector-borne diseases, there is a need to better understand their effectiveness in the context of climate change. Future research should examine how interventions may need to be adapted to account for changes in vector behavior and distribution.
5. The socioeconomic impact of climate change and vector-borne diseases: Climate change and vector-borne diseases can have significant impacts on communities, including loss of productivity, decreased economic opportunities, and increased healthcare costs. Future research should examine the socioeconomic impact of climate change and vector-borne diseases, as well as strategies to build resilience and mitigate these impacts.
6. Modeling disease transmission: Mathematical models are an important tool for understanding the transmission dynamics of vector-borne diseases. Future research should continue to develop and refine models that incorporate the complex interactions between climate, vectors, hosts, and interventions, as well as the uncertainties inherent in climate change projections.
7. One Health approaches: Vector-borne diseases are complex, multi-disciplinary issues that require integrated approaches that consider the interactions between humans, animals, and the environment. Future research should adopt a One Health approach that brings together experts from different disciplines to address the complex challenges posed by climate change and vector-borne diseases.
8. Data collection and sharing: There is a need for better data on the distribution and abundance of vectors, as well as the incidence and prevalence of vector-borne diseases. Future research should prioritize the development of standardized data collection and sharing protocols to facilitate cross-border and cross-disciplinary research.
9. Community engagement: Effective prevention and control of vector-borne diseases require the active involvement of local communities. Future research should prioritize community engagement and the development of culturally appropriate communication strategies to ensure that communities are aware of the risks posed by vector-borne diseases and are empowered to take action to protect themselves.
10. Policy and funding: Finally, addressing the impact of climate change on vector-borne diseases will require significant policy and funding support. Future research should aim to identify the policy and funding mechanisms that can best support the development and implementation of effective strategies to prevent and control these diseases in the context of climate change.

In conclusion, continued research is needed to fully understand the impacts of climate change on vector-borne diseases and to develop effective strategies to mitigate these impacts. By adopting a multi-disciplinary and integrated approach, we can better understand the complex interactions between climate, vectors, hosts, and interventions and develop effective policies and interventions to protect public health.There is a need for continued research to better understand the complex interactions between climate change and vector-borne diseases. By addressing these research gaps, we can develop more effective strategies to prevent and control these diseases and protect public health.

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