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THE ROLE OF ENVIRONMENTAL FACTORS IN THE INCIDENCE AND PREVALENCE OF VECTOR-BORNE DISEASES

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Abstract

There has been much deliberation over the potential impact of climate change on the danger of vector-borne illnesses. The discussion regarding the former has centered around the extent to which the occurrence and levels of risk of vector-borne diseases are influenced by factors that are dependent on climate or factors that are independent of climate. On the other hand, the discussion regarding the latter has focused on whether changes in disease incidence are caused by climate at all, and if so, whether they can be attributed to recent climate change. In this analysis, I examine the potential impacts of climate change on illnesses transmitted by vectors, such as mosquitoes and ticks. I also explore the techniques used to forecast these impacts and provide the current data indicating increases in disease risks associated with recent climate change. Forecasts have both overestimated and underestimated the impacts of climate change. The under-estimations of consequences mostly arise from a narrow emphasis only on the direct impacts of climate on disease ecology, while disregarding the broader implications on society's ability to manage and prevent vector-borne diseases. There is growing evidence suggesting that recent climate change may have an effect on some illnesses transmitted by vectors. However, in most cases, the available data series are either too short or non-existent, and the influence of variables unrelated to climate is significant. Therefore, it is difficult to safely ascribe changes in disease risk solely to climate change.

Keywords: climate change, vector-borne diseases, and public health, environmental microbiology, review.

1. Introduction

The health consequences of climate change have prompted significant attention to the influence on vector-borne diseases, as highlighted by Kovats and Haines (1995) and Githeko et al. (2000). Nevertheless, the issue of climate change has been a subject of intense dispute and disagreement among scientists, leading to significant doubt and misunderstanding over the current and possible future impacts of climate change. Undoubtedly, the effects of climate change on the prominent diseases of malaria and dengue have become a significant worldwide issue. These diseases, which were formerly referred to as the 'big two', now include three other diseases: yellow fever, chikungunya, and Zika, making them the 'big five'. These diseases are major contributors to illness and death worldwide (http://www.who.int/mediacentre/factsheets/fs387/en/), and are primarily transmitted from person to person (despite originally originating from animals) through Anopheles and Aedes spp. mosquitoes in tropical and subtropical areas.

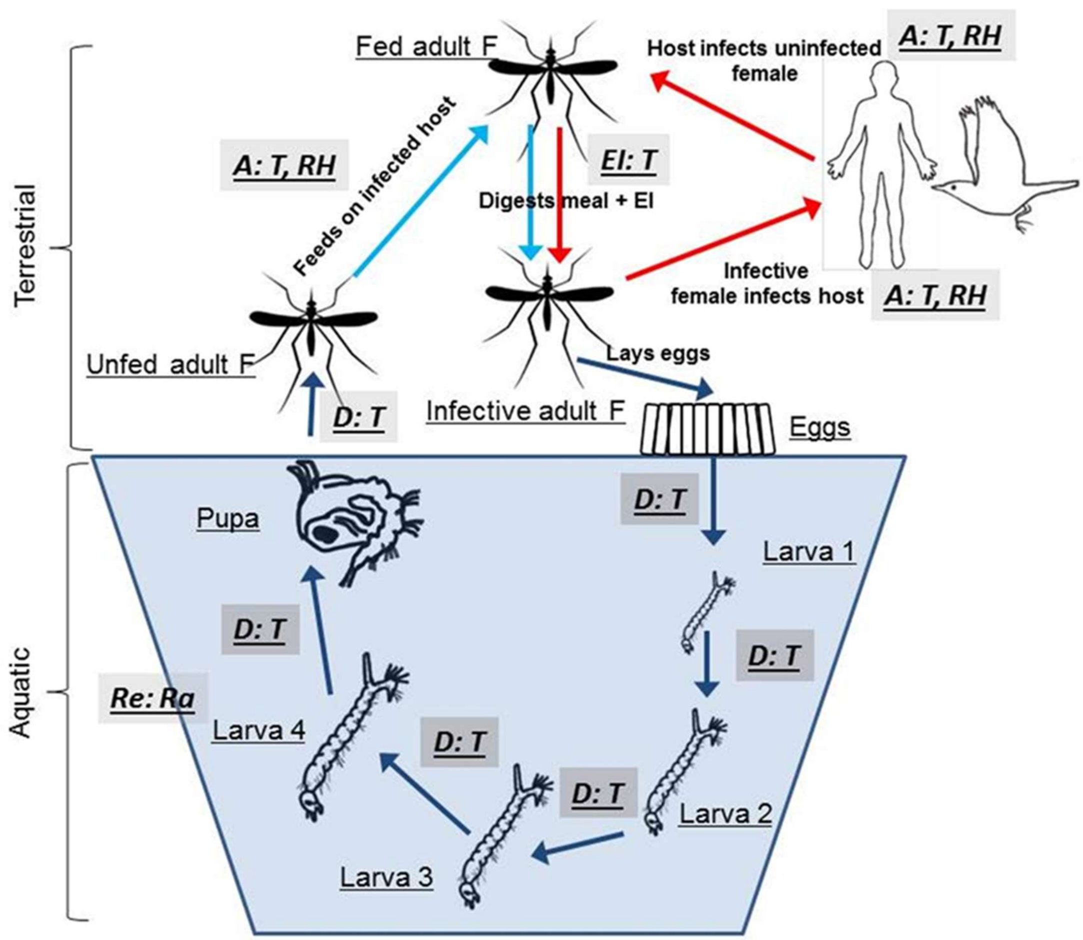
Vector-borne diseases are naturally influenced by weather and climate, but the discussion and lack of certainty regarding the effects of climate change on these diseases revolves around the extent to which weather and climate play a role in their occurrence and abundance, as opposed to human efforts to control them and their carriers (Lafferty 2009). Nevertheless, only concentrating on the effects of climate change on the biology of vectors and the transmission of vector-borne illnesses may overlook the broader socioeconomic repercussions of climate change, which might significantly damage our ability to manage and control these diseases. In addition, several vector-borne illnesses that are of public health importance, such as Lyme disease, West Nile virus, and viral horse encephalitides, are zoonoses that are sustained by animals. The prevalence of these diseases is mostly influenced by factors outside human control, as stated by Ogden et al. (2014c).

2. The impact of climate change on the vulnerability to vector-borne diseases

The vulnerability to vector-borne illnesses is inherently responsive to fluctuations in weather and climate. This has undergone thorough scrutiny by experts in the field, such as Medlock and Leach (2015), Parham et al. (2015), and Ogden and Lindsay (2016). I will provide a concise summary of these evaluations, which may also be seen in Figure 1. The presence and distribution of arthropod vectors are directly influenced by various weather and climate factors. These factors include the impact of low and high temperatures on the mortality rates of vectors, the influence of temperature and humidity on the activity and ability of vectors to find hosts, the effect of temperature on the development rates of vectors as they transition between life stages, and the impact of rainfall on the availability of breeding habitats for insect vectors. The climate also has indirect effects on the presence of vectors by influencing the characteristics of their habitat and the availability of animal hosts for their blood meals. The characteristics of a habitat have a crucial role in the survival of vectors by influencing the presence of shelters that provide protection during harsh weather conditions. This is especially significant for hard-bodied ticks, since they have extensive periods of growth between stages. The transmission cycles of vector-borne pathogens are directly influenced by climate and weather conditions. This is due to the effect of temperature on the length of the extrinsic incubation period of infections in insect vectors. This time is critical in deciding whether insect-borne illnesses may survive or not. The populations of vertebrate hosts are influenced by the features of their habitat. The biodiversity of hosts, as well as changes in biodiversity, may affect the transmission of vector-borne zoonoses, particularly those that rely on animals as the primary reservoirs (Cable et al. 2017).

Figure 1. The direct impact of temperature and weather on the populations of vectors and the transmission of vector-borne pathogens, using the possible impacts on West Nile virus transmission as an example (adapted from Ogden and Lindsay, 2016).

Anticipated climatic changes include rising temperatures, alterations in geographical rainfall patterns, heightened climate variability, and an escalation in the frequency and intensity of severe weather phenomena. Therefore, a changing climate may effect all of the climate- and weather-dependent aspects mentioned above, leading to changes in the suitability of settings for vectors and vector-borne illnesses to flourish in terms of their location and timing. The anticipated outcome is alterations in the spatial and seasonal patterns of vector-borne illness incidence, as well as variations in the degrees of risk associated with these diseases. The shifting dynamics of host communities, vectors, and diseases are anticipated to influence the fitness



landscape of various genetic variations of microbes and vectors. This might potentially modify the physical condition and number of different types of disease-causing organisms and carriers, and lead to the development of new strains and species that are of importance to public health (Gortazar et al. 2014).

Several vector-borne illnesses are now prevalent in tropical and subtropical areas, but not in temperate regions. Due to this rationale, as well as the anticipation that global warming would happen sooner and be more intense towards the poles according to the IPCC 2013 report, nations with temperate climates may face the greatest risk from the introduction and re-emergence of illnesses transmitted by vectors. According to Ogden and Lindsay (2016), there are three main anticipated risks. Long-term changes in temperature and rainfall patterns may lead to an increased risk of endemic vector-borne illnesses. Additionally, mosquito-borne diseases may become more widespread as the vectors and transmission cycles of pathogens adjust to the growing climatic variability and severe weather events. Furthermore, vector-borne illnesses have the potential to migrate towards the poles (or higher elevations in mountainous areas) and expand their distribution to locations where they are now absent. Furthermore, climate change can heighten the risk of the spread of 'exotic' tropical/subtropical vector-borne diseases, which are typically found in distant regions. This can occur through multiple mechanisms, including the direct enhancement of climatic conditions in currently non-endemic countries, the amplification of vector and pathogen populations in regions where they are already present (due to both direct impacts on their biology and indirect socioeconomic factors), and the increased likelihood of introduction through heightened international migration. Figure 2 is an instance of the potential outcomes by examining the effects on a single nation.

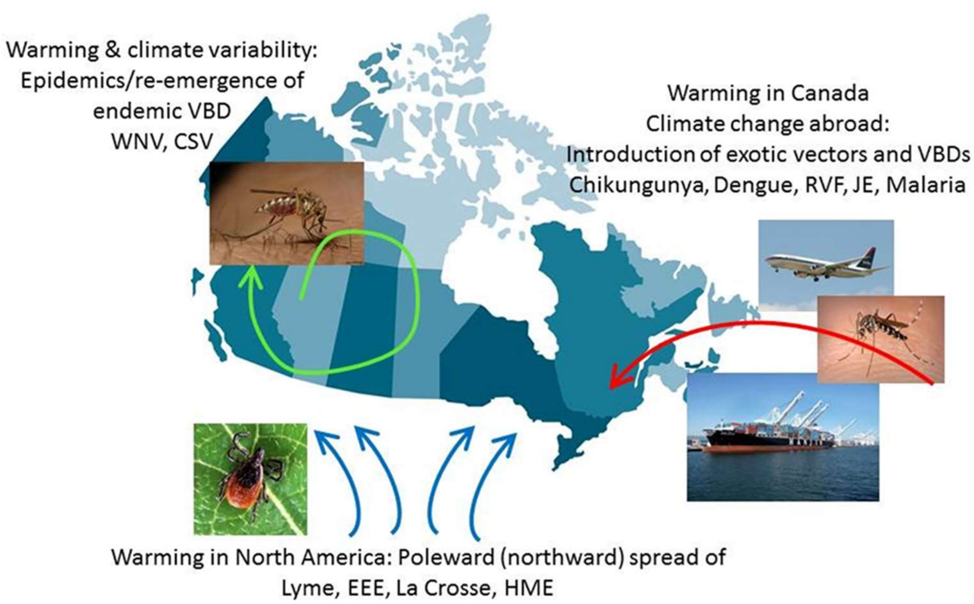


Figure 2. The potential effects of climate change on the altering hazards associated with vector-borne illnesses.

3. The current evidence on the impact of climate change on vector-borne diseases

The existence of scientific data would undeniably be the most influential factor driving public health policy on climate change and vector-borne illnesses. One of the most debated topics about climate change and vector-borne illnesses is whether there is any existing data to support the idea that climate change affects their incidence. The procedure of establishing evidence involves two steps: first, detecting a change in the risk of a vector-borne illness, and second, attributing this shift to recent climate changes (Ebi et al., 2017). To achieve detection and attribution, it is necessary to conduct systematic surveillance or other forms of monitoring over extended periods of time, often spanning decades. This allows for the comparison of evolving illness patterns with corresponding changes in climatic patterns. High-quality datasets with sufficient duration for this purpose are scarce. Additionally, considering that the majority of the Earth has only recently started to witness the initial impacts of climate change, it is not surprising that there is a lack of evidence linking changes in vector-borne disease occurrence and risk levels to recent climate change.

There is evidence indicating that climate change has affected some illnesses transmitted by vectors, regardless of their influence on public health. One of the first instances of this is the spread of Blue-tongue virus (BTV) from North Africa to a warmer Europe. The growth of BTV is believed to be driven by a combination of global warming, which enhances the appropriateness of the environment for BTV Culicoides spp. vectors, as well as the capacity of these vectors to transmit and persist the virus throughout winter (Purse et al. 2005). Considerable effort has been made to find comparable evidence for significant vector-borne illnesses like malaria, but obtaining robust evidence for these diseases has proven challenging. However, there is initial evidence of climate change affecting some vector-borne illnesses. In the following, I provide a concise overview of several attempts made so far to identify and assign causes to the impacts of climate change on illnesses transmitted by vectors.

The detection and attribution of the impacts of climate change on malaria incidence have been just as contentious as the previous discussion on predicting the consequences of climate change. The present geographic distribution of malaria is mostly influenced by previous and ongoing attempts to restrict both vectors and transmission, as well as by climatic conditions (Reiter 2001; Reiter et al. 2004). Consequently, much attention has been directed into investigating the potential impacts of climate change on altering the highest altitude at which diseases may be transmitted in the highlands of eastern Africa. The high vulnerability of this area to climate is shown in the pronounced seasonal pattern of malaria incidence (Hay, Snow and Rogers 1998).

The climate sensitivity mechanism in this region primarily involves the interplay between temperature and various factors related to malaria. Specifically, it affects the extrinsic incubation period of malaria parasites (which decreases as temperature rises), the survival of mosquitoes (which increases with higher temperatures at this altitude), and the length of the gonotrophic cycle (which shortens with warmer temperatures), consequently impacting the biting rate (which increases with higher temperatures) (Lindsay and Burley 1996). Surveillance has definitively detected yearly fluctuations in the occurrence in this area, and several scientists have linked them to meteorological or climatic trends (Zhou et al. 2004). Nevertheless, there has been disagreement over the data suggesting that these changes may have been linked to climate-related variables as opposed to causes unrelated to climate, such as the development of resistance to antimalarial medications (Hay et al. 2002; Reiter et al. 2004). Pascual et al. (2006) and Stern et al. (2011) provided more evidence, using a longer dataset that clearly demonstrates the increasing trends in temperature in recent years and its correlation with the frequency of malaria. This link has been seen in other locations of the globe, as supported by Siraj et al. (2014).

4. Conclusion

Continued efforts are needed to forecast the effects of climate change on illnesses transmitted by vectors. These efforts will help shape public health policies and programs aimed at minimizing the burden of new and recurring vector-borne diseases. Optimally, model-based risk assessments should encompass the evaluation of both climate-dependent and climate-independent factors that directly impact the transmission of vector-borne diseases. Additionally, these assessments should also account for the indirect effects of climate change on vector-borne diseases, which may arise as a result of the socioeconomic consequences of climate change on our societies. It is necessary to perform surveillance for illnesses transmitted by vectors, but the degree of effort should be adjusted according to the current risk level (Murphy, Vaux and Medlock 2013; Kampen et al. 2015).

Under various situations, this will entail conducting entomological surveillance, or employing alternative techniques like sentinel animal surveillance, which serves as an early warning system prior to human illness cases and aids in validating and enhancing model-based forecasts. In order to attribute the changes in hazards of vector-borne diseases to climate change, it would be necessary to establish long-term monitoring programs spanning many decades. Ultimately, it is crucial for public health authorities facing potential threats to have the necessary measures and strategies in place to safeguard the well-being of the population against the emergence and resurgence of diseases transmitted by vectors. In this context, the specific role of climate change as the root cause becomes less significant.

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