Chapter

Vector-Borne Disease and Climate Change

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Abstract

Many arthropod species are vectors of numerous diseases of humans and animals, which include ticks, fleas, sandflies, mosquitoes, triatomine bugs, and blackflies. The vector transmits bacteria, viruses, and protozoa from one host to another causing various diseases, such as dengue fever, West Nile Virus, Lyme disease, and malaria. They are scold-blooded animals and very sensitive to the fluctuation in climatic factors. Changing climate influences the survival, reproduction, abundance, and spatiotemporal distribution of vectors throughout the year and the rate of development and survival of pathogens within the vector-host. Climate change is among the prime factors that influence the survival, reproduction, distribution, and density of disease vectors.

Keywords: arthropods, vector, pathogen, diseases, climate

1. Introduction

Vector-borne diseases (VBDs) continue to contribute significantly to the global burden of disease and cause epidemics that disrupt health security and cause wider socioeconomic impacts around the world [1]. A vector is an organism (most often an arthropod) that transmits an infectious pathogen from an infected human or animal host to an uninfected human. The World Health Organization (WHO) and other scientists identify the major global VBDs as malaria, dengue, chikungunya, yellow fever, Zika virus disease, lymphatic filariasis, Chagas disease, leishmaniasis, Japanese encephalitis, etc. (**Table 1**). Deadly pathogens and parasites are transmitted by arthropods [34], and the increasing global human and animal populations are threatened by such epidemics and pandemics [35]. Arthropod-borne diseases are referred to as viruses, bacteria, and protozoans transmitted either to animals or humans by blood-sucking arthropods [36]. There are over 700 known arthropod-borne viruses and at least 80 immunologically distinct types that cause diseases in humans [37].

Insect-borne diseases					
Microbial class	**Pathogen**	**Vector**	**Disease**	**Effected or host organisms**	**Selected references**
Protozoans diseases	Plasmodium sp.	*Anopheles* sp.	Malaria	Humans and animals	[2, 3]
	Trypanosoma brucei	Glossina (tsetse fly)	Sleeping sickness, African trypanosomiasis	Humans	[4–6]
	Leishmania parasite	Phlebotomus papatasi (Sand fly)	Leishmaniasis	Animals	[4, 7]
	Trypanosoma cruzi	Triatomine bug	Chagas disease	Humans and animals	[4]
	Chikungunya virus	Aedes aegypti, Ae. Albopictus	Dengue	Humans	[8, 9]
Viral diseases	Flavivirus	*Culex sp.*	St. Louis encephalitis	Humans	[10]
	Alphavirus or Chikungunya virus	*A. aegypti*	Chikungunya fever	Humans and animals	[11, 12]
	Flavivirus Chikungunya virus	A. aegypti, Ae. Africanus	Zika disease	Humans and animals	[13]
	Chikungunya virus	*A. aegypti*	Yellow fever	Humans and animals	[11, 14]
	Flavivirus sp.	*Culex pipiens* and others	West Nile fever	Humans	[11, 14]
	Orbivirus spp.	*Culicoides* midges or *C. imicola*	Bluetongue disease	Animals	[15–17]
	Flavivirus	*Culex* spp.	Japanese encephalitis	Humans and animals	[4]
	Phlebovirus	*Aedes* spp.	Rift valley fever	Humans and animals	[18, 19]
	Yersinia pestis	*Xenopsylla cheopis*	Plague	Humans	[20, 21]

Insect-borne diseases					
Bacterial diseases	*Flavivirus* sp.	*Ixodes ticks*	Tick-borne encephalitis	Animals	[4]
	Borrelia recurrentis	*Ornithodoros turicata and Pediculus humanus*	Relapsing fever	Humans and animals	[22]
	Rickettsia prowazekii or *Rickettsia typhi*	X. cheopis	Typhus	Humans	[23, 24]
	Bartonella Quintana	*P. humanus corporis*	Trench fever	Humans	[25–27]
	Wuchereria bancrofti	*Mansonia uniformis*	Malayan or lymphatic filariasis	Humans	[28]
Nematode	*Brugia malayi*	*Aedes togoi* and *C. pipiens*	Bancroftian filariasis	Humans	[29]
	Brugia malayi	*A. togoi* and *C. pipiens*	Bancroftian filariasis	Humans	[29]
Tick-borne diseases					
Protozoans disease	*Anaplasma marginale*	Ixodes sp.	Lyme disease	Humans	[11]
Bacterial disease	*Borrelia theileri*	Ixodes scapularis	*Anaplasmosis*	Animals	[30]
	Coxiella burnetii	*Rhipicephalus boophilus*	Bovine borreliosis or Tick fever	Animals	[30]
	Rickettsia rickettsia	Ixodes ricinus	Q fever	Animals	[31]
	Francisella tularensis	*Dermacentor variabilis*	Rocky Mountain spotted fever	Animals	[24, 32]
		Dermacentor andersoni, and *Haemaphysalis otophila*	Tularemia	Animals	[33]

Table 1.
Vector-borne diseases and their vector insects.

Among arthropods, insect vectors that transmit pathogens are more infectious mainly after the ingestion of the pathogen through a blood meal on an infected host, followed by the pathogens amplification/circulation in the insect's body, before the vector becomes infectious [38]. Most of the arthropod-borne viral infections are transmitted by mosquitoes. Transmission of these viruses to humans involves complex processes influenced by the mosquito and viral genetics, environmental factors, and human activities [39]. In human memory, the most devastating ABDs are not malaria or dengue or Ebola, but the plague named the Black Death, and in Europe, the Black Death is still considered the plague par excellence [40]. The major problem is caused by the invasion of exotic species of insects due to climate change [41].

The climatic factors that directly influence VBDs ecosystems are mainly temperature and rainfall [42]. Long-term variations in temperature and precipitation, climatic extremes (heatwaves, cyclones, and flash floods), quality of air, rise in low-lying coastal regions, sea level, and numerous implications on systems of food production and water supplies all have a direct impact on health. According to estimates, VBDs account for even more than 17% of the burden of communicable diseases worldwide, and more than 700,000 VBD deaths are documented each year globally [43].

2. Protozoans insect-borne disease

The health of hundreds of millions of individuals globally is seriously threatened by parasitic protozoans that are known to transmit diseases to humans. As a result of their combined infection, over a million people die each year [44, 45].

2.1 Malaria

Human malaria is caused by five species of plasmodium parasites and is transmitted by female Anopheles mosquitoes. Among vector-borne diseases, malaria is the major killer, causing an estimated 620,000 deaths in 2017 (most occurring in Africa) [46]. According to Rahmah et al. [47], malaria is currently endemic and spread by anopheline mosquitoes in far more than 80 countries with a combined population of about 3 billion people. Malaria is particularly prevalent in Sub-Saharan Africa, where even more than 85% percent of cases and 90% of deaths occur, mostly in children under the age of five. Malaria still has a staggeringly negative impact on the public's health (228 million cases globally, with 214 million, which is 93% of the total, reported in Africa alone), and recent catastrophic outbreaks have wracked many parts of the world [48, 49].

2.2 Sleeping sickness

African Trypanosomiasis, also known as sleeping sickness is caused by a microscopic parasite of the species *Trypanosoma brucei*. It is transmitted by the tsetse fly (*Glossina* spp.), which is only found in Sub-Saharan Africa [6]. The disease was perceived to be spreading across the continent from the French, Portuguese, and Belgian territorial interests in West and Central Africa towards the British and German colonies in East Africa [50]. *Trypanosoma brucei* is usually fatal within 3 years in the absence of treatment [51]. It is estimated that thousands of people are infected and millions are at risk, 1.35 million are lost due to sleeping sickness; mortality related to sleeping sickness is ranked ninth out of 25 among the human infectious and parasitic diseases in Africa [52].

2.3 Leishmaniasis

Leishmaniasis is caused by infection with Leishmania parasites, which are spread by the bite of phlebotomine sand flies. There are several different forms of leishmaniasis in people [7]. The WHO has obtained discounts on some medications to treat the disease. It is classified as a neglected tropical disease. The disease may occur in a number of other animals, including dogs and rodents. Visceral leishmaniasis is endemic in 78 countries but mainly affects economically disadvantaged populations in east Africa, Southeast Asia, and Brazil [43]. Approximately 98 nations and 4–12 million persons worldwide are now afflicted. Each year, there are about two million new cases and 20–50 thousand fatalities occurred. There are 200 million individuals who reside in regions of Asia, South and Central America, Africa, and Southern Europe where the disease is prevalent [53].

3. Viral insect-borne diseases

The viruses that cause diseases spread by insects are within a unique category and have a wide range. They are categorized as arboviruses and are made up of a diverse range of viruses that are spread by hematophagous arthropod vectors. Their primary vectors are ticks, sandflies, and mosquitoes, which are most common in tropical areas. Arboviruses like the chikungunya virus and yellow fever virus are the ones responsible for the most well-known and dangerous arthropod-borne infections. However, we must give the Flaviviridae family a unique place (Dengue, St. Louis encephalitis, Yellow fever, and West Nile encephalitis). Regarding vector-borne disease, viruses differ from one another in terms of how they behave inside of their hosts. Since humans are still unable to replicate these arboviruses to high enough titers, most human infections with them are accidental [11].

3.1 Dengue

Dengue is the most important mosquito-borne disease in the world. It is spread in tropical and subtropical regions, but the pathogen is an arbovirus, which is the general name assigned to viruses affecting mankind [9].). The viruses that cause dengue are from the Flavivirus genus, and *Aedes aegypti*, followed to a lesser extent by *Ae. albopictus*, is the primary vector. In contrast to the situation with malaria, the incidence of dengue has rapidly increased globally in recent decades. The primary distinction between dengue fever and malaria is that a virus causes both the infection and the symptoms in dengue fever [54]. Until 2005, the stated data estimated that approximately 2/5 of the world's population was susceptible to contracting dengue. However, as many instances are underreported and incorrectly classified, the number of dengue cases, like those for other insect-borne diseases, must only be used as an indication. According to reported data, 50–100 million cases of acute febrile fever occur each year, including almost 50,000 cases of severe dengue, putting more than 2 and half billion people, or more than 40% of the world's population, at risk of contracting the disease [55].

3.2 St. Louis encephalitis

St. Louis encephalitis virus (SLEV), an arthropod-borne flavivirus, can cause disease presentations ranging from mild febrile illness to severe encephalitis. It is

transmitted by *Culex* sp.; birds are usually the hosts, but it can also affect humans and other hosts [56]. This disease is currently present in Canada, Mexico, and Central and South America. The clinical symptoms of this encephalitis are often not manifested, except during epidemics, wherein children and elderly are the most susceptible, with mortality 5–20% [11]. There have been cases documented across the nation, but the Mississippi Valley, the Gulf Coast, and more recently the Southwest have seen the majority of recurrent outbreaks and epidemics. SLE cases are more common in the late summer and early fall in temperate regions of the United States. In southern states, cases can happen at any time of year [57].

3.3 Chikungunya fever

Chikungunya virus (CHIKV) is an alphavirus of the Togaviridae family vectored by *Aedes* Mosquitoes [58]. CHIKV is considered as an important emerging public health problem in both tropical and temperate countries, where the distribution of the Aedes mosquito vectors continues to expand [12]. The number of cases reported to the PAHO regional office in 2016 was 349,936 suspected and 146,914 laboratories recorded incidents, which is a 50% decrease from the last previous year. Brazil reported 265,000 suspected cases, followed by Bolivia with 18,000 cases, Colombia with 19,000 cases, and Pakistan with 8387 cases [59]. The year 2016 was the first one that autochthonous transmission of chikungunya was reported in Argentina, following an outbreak of more than 1000 suspected cases [11].

3.4 Zika disease

Ae. albopictus is capable of hosting the Zika virus and is considered a potential vector for transmission among humans. This tiger mosquito is an epidemiologically important vector for the transmission of many relevant viral parasites, including yellow fever virus, dengue fever, and chikungunya fever [60, 61]. The Zika virus is the cause of the Zika disease and is a Flavivirus. The vector of the Zika virus is an *Aedes* mosquito, which can bite monkeys and humans [13]. Since 1950, ZIKA disease has been known to occur within a narrow equatorial belt from Africa to Asia. From 2007 to 2016, the virus spread eastward, across the Pacific Ocean to the Americas, leading to the 2015–s2016 Zika virus epidemic [62]. Brazil announced a connection between infection with Zika virus and microcephaly in October 2015. The Americas, Africa, and other parts of the world quickly saw outbreaks and transmission evidence. Eighty-six nations and territories in all have reported cases of Zika infection caused by mosquitoes [63]. From April 2015 to November 2016, the Zika virus, which causes Zika disease, spread throughout the Americas from Brazil. In November 2016, the WHO pronounced the outbreak to be over, but added that the virus continues to be "a highly important and long-term concern." In Brazil, the Zika virus is thought to have infected 1 and half million people, and between October 2015 and January 2016, more than 3500 newborn microcephaly cases were confirmed [64].

3.5 Yellow fever

Ae. aegypti is the most important vector of this disease. The virus spreads mostly by contact between monkeys; however, it is also capable of infecting people through a different vector. Every year, this illness results in 30,000 fatalities and 200,000 clinical cases. The majority of the cases, which affect mostly young people, are recorded

from Africa, primarily the Sub-Saharan areas The disease can be fatal, acute, mild, and even unapparent [11]. Yellow fever is an acute viral hemorrhagic disease transmitted by infected mosquitoes; the infected mosquitoes of the *Aedes* spp. transmit the virus from person to person [5].

3.6 West Nile fever

Again, this disease is caused by a virus of the genus Flavivirus and the vector is an *Aedes* mosquito, aided in this case by *Culex* sp. The disease has been reported in regions of all populated continents. Birds, horses, and people can all contract West Nile fever, which has a variety of symptoms, including none at all, up until the point of death. The first virus cycle affects a number of bird species and mosquitoes, which helps the virus replicate. Secondary mammals, namely, horses and humans, are the virus's other targets [14, 65]. About 1 in 5 people who are infected develop a fever and other symptoms. About 1 out of 150 infected people develop a serious, sometimes fatal, illness [66]. Birds are exposed to the West Nile virus through the bites of infected mosquitoes. By biting infected birds, mosquitoes catch the disease. Crows and other scavengers or predatory birds like hawks and owls may contract the disease through eating sick or deceased West Nile virus-infected birds. It is possible for birds to contract the disease if they ingest infected mosquitoes.

3.7 Bluetongue disease

Bluetongue is a noncontagious, midge-borne viral disease affecting ruminants (mainly sheep and less frequently cattle, goats, antelope, deer, camel, and dromedaries). Bluetongue virus (BTV) is transmitted by Culicoides biting midges [67]. BT is a complex multi-vector, multi-host, and pathogen disease whose prevalence fluctuates, reemerging after protracted absences. The majority of transmission occurs silently in disease-resistant animals, or short devastating phenomena influencing in preference specific breeds of sheep that are economically very important for the production of high-quality wool. Most common reservoir is cattle, which can also be sub-clinically infected for a protracted infection. The name of the illness comes from its most noticeable symptom, the characteristic blue iridescent colors of the tongues of all infected animals. Although the target of this disease is limited to sheep, cattle, and some species of deer and camelids, the effects can be epidemic and devastating, causing alerts for immense economic damage. [15, 16, 68]. Changes in climate conditions in Mediterranean countries could make possible stable introductions, driving the spread of vectors and pathologic agents [17, 67, 69].

3.8 Japanese encephalitis

Japanese encephalitis (JE) is a zoonotic virus spread by vectors. In Asia, the JE virus (JEV) is the most common cause of viral encephalitis. Nearly all Asian nations, whether subtropical, temperate, or tropical, are affected by JE, which has spread to new regions through the introduction of infected vectors. The 24 nations, mostly in the WHO Western Pacific Regions and South East Asia that are now thought to be at risk of JE are home to an estimated 3 billion people. JEV repeats in an enzootic cycle in wading birds and pigs, which act as amplifying hosts and are the primary vectors of Culex mosquitoes that transmit the disease [4, 70]. It is estimated that 67,900 clinical cases of JE occur annually despite the widespread availability of the vaccine, with

approximately 13,600 to 20,400 deaths. In some countries, such as Bangladesh which has no JE vaccination program, over 50% of cases occur in adults [71].

4. Bacterial insect-borne disease

4.1 Trench fever

Trench fever is a louse-borne disease caused by the gram-negative bacterium *Bartonella quintana* and observed originally in military populations during World Wars I and II. The only source of this Bartonella infection is humans. When infectious lice (Pediculus humanus corporis) excrement is rubbed into scratched skin or the conjunctiva, it can spread B. quintana to people. Trench fever is resurfacing among the US's homeless population and is endemic in México, Tunisia, Poland, Eritrea, and the former Soviet Union [26]. Trench fever had a major effect on the manpower resources of both the Allies and the Central Powers. An estimated 800,000 cases occurred among the Allies on the Western Front during World War I [72].

4.2 Relapsing fever

Spirochetes that cause tick-borne relapsing fever (TBRF) are neglected pathogens, and diagnosis of this disease is challenging because of its nonspecific manifestations [73]. Infection with *Borrelia* spp. known as relapsing fever can result in repeated episodes of fever, headache, aches in the muscles and joints, and nausea. Relapsing fever comes in three different forms: Relapsing tick-borne fever (TBRF), relapsing fever brought on by louses (LBRF), chronic *Borreliosis miyamotoi* (sometimes called hard tick relapsing fever). The western US is where TBRF occurs, and staying in shabby, rodent-infested cabins in the mountains is typically associated with it [27, 73, 74]. The mortality rate is 1% with treatment and 30–70% without treatment [75]. In Texas, TBRF is frequently linked to cave exposures. LBRF is transmitted by the human body louse and usually occurs in refugee settings in developing parts of the world [76].

4.3 Plague

The gram-negative coccobacillus Yersinia pestis, which is 2 μm long, is what causes the plague. Pneumonic, systemic infection, and bubonic plague are the three primary illness manifestations caused by the infection in humans. The final one stands out and is well-known [21]. It spreads in the typical arthropod-borne illness triangle of pathogen, vector, and victim. The vector in this instance is the Oriental flea (Xenopsylla cheopis), which feeds on an infected animal and regurgitates blood containing parasitic cells [20, 77].

5. Tick-borne disease

Ticks are ectoparasites that are common throughout the world, and their eco epidemiology is directly tied to environmental factors. They are required hematophagous ectoparasites that act as reservoirs or carriers for dangerous bacteria, viruses, protozoa, rickettsia, and another fungus while they feed on their hosts. The next

vector group that mostly spreads infections to humans and primarily affects animals in the disease transmission process is the tick [78].

5.1 Lyme disease

Lyme disease is the most common disease spread by ticks in the Northern Hemisphere, with an estimated 300,000 infected people a year in the USA alone and 65,000 people a year in Europe. The infection is caused by a bacterium of the genus *Borrelia,* spread by ticks, but it is transmitted to humans by the bites of infected ticks of the genus *Ixodes*. The disease is more common in the spring and early summer [11].

In Europe, *Ixodes ricinus* spreads a large number of tick-borne infections, such as *Lyme borreliosis* and tick-borne encephalitis. Potential habitat expansion in northern Europe was forecast by models, along with warmer winter weather conditions including temperature rise. These circumstances might make it easier for more ticks to survive the winter and raise the risk of tick bites [79].

The higher temperature was found to be the most important determinant of environmental suitability for the establishment of the Lyme disease Ixodes tick vector in southern Canada, where it has been spreading [80]. Milder and shorter winters in Quebec, Canada are associated with the northern spread of the white-footed mouse, the primary reservoir host for the Lyme disease pathogen *Borrelia burgdorferi* [81].

5.2 Tularemia

Tularemia is a highly contagious disease occurring principally in wild animals, but it may transmit to farm animals, causing septicaemia and high mortality. *Francisella tularensis* is the causative organism [33]. *F. tularensis* has a wide host range and is recorded in over 100 species of bird and wild and domestic animals [82]. The mortality rate is 50%, especially in young animals. Transmission occurs chiefly by the bites of the wood tick, *Dermacentor andersoni*, and from *Haemaphysalis otophila*. Tularemia is primarily restricted in its occurrence to countries in the Northern Hemisphere. In North America, the disease is most prevalent in farm animals in the North Western states of the USA and the adjoining areas of Canada [83].

6. Importance of climate change on vector-borne disease (VBD)

There is no doubt that a suitable climate is necessary for the persistence or emergence of a vector-borne disease [84]. Since a warmer temperature and shifting rainfall patterns may produce favorable habitats for viruses and climate-sensitive vectors (such as mosquitoes and ticks), climate change has an impact on how VBDs are transmitted. Climate change is recognized as a significant driver affecting the epidemiology and dissemination of VBDs on various time scales, albeit the implications are exacerbated by nonlinear feedback, intrinsic in the dynamics of infections [85].

6.1 How does climate affect VBD

Through a variety of mechanisms, including direct impacts on the pathogens, the vector, nonhuman hosts, and humans, climate can influence the dynamics of transmission, geographic spread, and reemergence of vector-borne diseases. Climate change can change entire ecosystem habitats, including urban habitats,

which can either benefit or harm vectors or nonhuman hosts. This is in addition to getting direct effects on specific species [84].

6.2 Warm climate and changing rainfall

Since arthropods and many other vectors are ectotherms, it is anticipated that with rising temperatures, both the rate of pathogen development and the length of the transmission season in some endemic locations, as well as the abundance, survival, and feeding activity of vectors, will rise. (The other dengue vector, *Aedes albopictus*, has already shown widespread growth into further temperate regions; it is unknown what impact climate change will play in this.) If endemic areas get so hot that vector survivability or feeding is hindered, there is also a chance that the prevalence of dengue or other vector-borne diseases would diminish. But the effects of excessive heat would still be very bad in these regions. Rainfall and vector abundance have a complicated and context-specific relationship [86].

6.3 Climate is an effective determinant of VBD

Vector-borne diseases are among the most well studied diseases associated with climate change, owing to their large disease burden, widespread occurrence, and high sensitivity to climatic factors [1]. The natural environment and human systems are also affected by climate and weather conditions in a variety of more indirect ways. For instance, a drought may have an impact on water storage, soil use and irrigation techniques, and population movement, which in turn may have an impact on vector ecology and human infection exposure [87]. The most direct links exist between temperature and the rates of biting, reproduction, and survival of vectors as well as the development and survival of the infections they carry. Additionally, precipitation has a significant impact on diseases that are spread by vectors with aquatic developmental stages, such as mosquitoes, as well as diseases that are spread by vectors without any such stages, including ticks or sandflies [88]. The impact of climate on the transmission of disease may be obscured, for instance, when the pathogens take a long time to develop in the host or when the vectors are relatively protected from weather and climate because they spend all of their time indoors (such as triatomine bugs, which transmit Chagas disease) (such as the nematode worms, which cause filariasis). Climate change can have quite varied effects on diseases even whose transmission cycles appear to be identical. Consider the differences between malaria and dengue, two of the most significant and thoroughly researched vector-borne diseases, both anthroponoses spread by mosquitoes [55].

7. Future impact of climate change

This chapter focuses on major changes in vector and pathogen dissemination that have been observed in recent years in temperate, Arctic, Peri-arctic as well as tropical highland regions. These changes have been predicted by scientists all over the world. In addition, if we do not mitigate and respond to climate change, further changes are probably coming. The movement of people, animals, and goods; existing control measures; the availability of efficient medications; the standard of health services; human behavior; and political stability and conflicts are just a few of the important factors that influence the spread and intensity of human diseases.

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