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Zika Virus Vectors

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Abstract **Background:** An outbreak of Zika virus has been recently reported in the Americas, specifically in northern Brazil. Due to the fact that the main vectors of the disease, *Aedes aegypti* and *A. albopictus*, are widely distributed in the region, epidemics of a greater magnitude are expected to develop in the short term. **Methods:** References about the implications on disease transmission, geographical distribution, breeding and bionomics of the vectors most frequently associated with virus transmission have been reviewed. **Conclusions:** This research aims to sensitize health teams and the general public to this infection, which shares the same vectors and some clinical features with dengue and Chikungunya, both common diseases in the Americas.

Keywords: *breeds, distribution geographical, aedes, virus, zika*

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1. Introduction

Zika virus is a member of the Flaviviridae family and is transmitted to humans by mosquitoes. It was isolated from sentinel monkeys, mosquitoes, and sick persons in Africa and Southeast Asia [1,2]. It is related to other pathogenic vector-borne flaviviruses including dengue, West-Nile and Japanese encephalitis viruses but produces a comparatively mild disease in humans. Zika virus is considered an emerging infectious disease with the potential to spread to new areas where the Aedes mosquito vector is present.

The symptoms of this disease are characterized by low grade fever (less than 38.5°C) frequently accompanied by a maculopapular rash. Other common symptoms include muscle pain, joint pain with possible swelling (notably of the small joints of the hands and feet), headache, pain behind the eyes and conjunctivitis. As symptoms are often mild, infection may go unrecognized or be misdiagnosed as dengue or chikungunya virus [3].

In 2007, Zika virus caused an outbreak in the island of Yap in the Pacific [2]. This was the first documented transmission outside of its traditional endemic areas in Africa and Asia [2]. *Aedes hensilii* was the vector identified as possibly involved, although the virus was not found in the mosquito. In Africa, the first isolated human virus was described during an outbreak in eastern Nigeria by MacNamara (1954) [4]. Since then, small animal diseases and epidemics have occurred in Africa and Asia [5]. Serological and entomological reports of Zika virus infection were later performed in different areas in Africa (Burkina Faso, Ivory Coast, Egypt, Central African Republic, Mozambique, Nigeria, Uganda, Central African Republic and Senegal) [6]. Between 1968 and 2002, 606 strains, including 10 human ZIKV strains were isolated in countries of Central and West Africa reported by the WHO Collaborating Centre for Arbovirus and Viral Hemorrhagic Fevers of the Pasteur Institute in Dakar [7,8]. Subsequently, an outbreak was reported in French Polynesia, which began at the end of October 2013. About 10,000 cases were recorded with approximately 70 severe cases, with neurological complications (Guillain Barre Syndrome, meningoencephalitis) or autoimmune disorders (thrombocytopenic purpura and leukopenia). In relation to this, a research study was conducted to determine the association between these complications and the co-primary or secondary infection by other flavivirus, especially dengue virus [5]. Related vectors were *Aedes aegypti* and *Aedes polynesiensis*.

In 2014, cases were also recognized in New Caledonia and Cook Islands. So far, it has not been reported any deaths attributed to Zika virus infection in any of the outbreaks. In the past seven years, cases have been reported sporadically in travelers (Thailand, Cambodia, Indonesia and New Caledonia). However, in February 2014, public health authorities of Chile confirmed a case of indigenous transmission of Zika virus in Easter Island (Chile) [1]. It coincided with the presence of other foci of transmission in the Pacific Islands: French Polynesia, New Caledonia and the Cook Islands [9]. The virus was reported in the month of June of that year, and was not detected at a later time.

In the month of May of that year the Brazilian Health Ministry confirmed the circulation of the virus, after identifying 16 samples in two states: Bahia and Rio Grande do Norte. That same month, another case was detected in the state of Sao Paulo, in a person with no travel history. According to the European Centre for Disease Prevention and Control (9), it was the first outbreak of the disease that has been documented in Latin America (Figure 1).

Recent outbreaks of fever by Zika virus in different regions of the world suggest the potential spread of this arbovirus across the territories with potential vectors (*Aedes*). In this sense, it is believed that the survival of

ZIKV in interepizootics may depend on the vertical transmission of the virus in *Aedes* [1].

Figure 1. Zika Virus Expansion. January 2016. Microbiology and Health Association

Africa (Burkina Faso, Cameroon, Ivory Coast, Egypt, Ethiopia, Gabon, Gambia, Kenya, Nigeria, Senegal, Sierra Leone, Somalia, Tanzania, Central African Republic, Uganda, Zambia), **Asia** (Cambodia, India, Indonesia, Malaysia, Pakistan, Philipines, Singapore, Thailand, Vietnam) **America** (Brazil, Chile, Mexico, Nicaragua, Guatemala, El Salvador, Honduras, Panama, Venezuela, Colombia, Paraguay, Haiti, Puerto Rico, St. Marteen, Martinique, Guyana, Suriname) **Pacific Islands and Oceania** (Cook Islands, Eastern Island, Micronesia, French Polynese, New Caledonia, Solomon Islands, Vanuatu).

Given the epidemiological alert in Colombia and Brazil by the presence of this new virus, the World Health Organization (WHO) issued a warning to be prepared for it. To this end, an alert was generated in all countries to be vigilant to detect and confirm infections, treat patients, implement communication strategies to ensure suitable conditions for the reduction of the presence of the disease-transmitting mosquito. In Ecuador, no cases of this new virus have been reported so far, but since the Zika virus resembles dengue behavior, it is recommended that any person presenting similar symptoms should go to the nearest health center to be evaluated by a specialist.

Considering the distribution of the disease, which is dependent on the distribution of *Aedes* mosquitoes competent to transmit viruses in South America, coupled with travelling due to either trade or touristic purposes, the scientific community must take action, along with the Public Health Ministry of the different regions, specially about Ecuadorians travelling to Chile, Brazil and other countries in the Americas, to be alert of a possible infection of the Zika virus.

The purpose of this study was to investigate the geographical distribution and bioecology vectors involved in the transmission of this arboviral disease. Considering the importance of this topic for human health, knowledge, identification and recognition of potential breeding grounds for the vectors that transmit the Zika virus have been some of the main objectives of this review. Identifying breeding sites of mosquitoes is essential to learn about their population dynamics and to exercise control over the transmission times of mosquito vectors.

2. Vectors

Aedes aegypti and *Aedes albopictus* have been involved in large outbreaks of Zika virus. Also, other species of this genus as *Aedes hensilli*, *Aedes polynesiensis*, *Aedes furcifer*, *Aedes taylori* and *Aedes luteocephalus*. [10]. Neither of these endemic species had been recognized as a vector before Zika virus, indicating that as this emerging disease spreads to previously unaffected countries, the potential exists for other endemic *Aedes* species to play a role in transmission (Figure 2).

2.1. *Aedes aegypti* (Linnaeus, 1762)

2.1.1. Geographical Distribution

Ae. aegypti is a species found in tropical and subtropical regions of America, Africa and Asia, and Southeast US, the Indian Ocean Islands and northern Australia [11]. This species was established in Europe in the early twentieth century and has recently been re-established in Madeira, and around the Black Sea in southern Russia, Abkhazia and Georgia. [9]

2.1.2. Breedings

Ae. Aegypti is closely associated with human environments and can breed indoor (flower vases, concrete water tanks in bathrooms), and artificial outdoor (vehicle tyres, water storage vessels, discarded containers) environments which serve to establish the vector breeds in clean water with low organic content and dissolved salts by laying eggs on the surface of the container at the height of the water-air interface [12]. Moreover, it has been shown that mosquitoes only use a narrow space between the water surface and the deeper areas which explains its presence in large variety of containers [13]. However, there is a trend to highlight the importance of including underground breeding of this species in surveillance programs and controls of it [14].

2.1.3. Bionomics

It is a species disseminated by man through the transport of its adults, eggs, larvae or nymphs in ships,

aircraft and land transport. Their habits are clearly anthropophilic and domestic, with location of their breeding sites in the home or its surroundings [15].

Ae. aegypti does not stray far from their breeding sites. Observations indicate that they can get away 200 to 300 meters and up to a kilometer or more. The dispersal distance accepted for this mosquito is less than 150 meters [16]. With the exception of the discovery of Reiter and Nathan [17], who were able to show in Puerto Rico a maximum dispersion of 840 meters. In this regard, most researches show 100-150 meters distance [18]. Reducing breeding sites in areas with presence of this vector promotes dispersion [19]. Another important aspect in relation to the adult mosquito is the fact that the activity is limited below 14 °C and oviposition is affected below 17 °C [18].

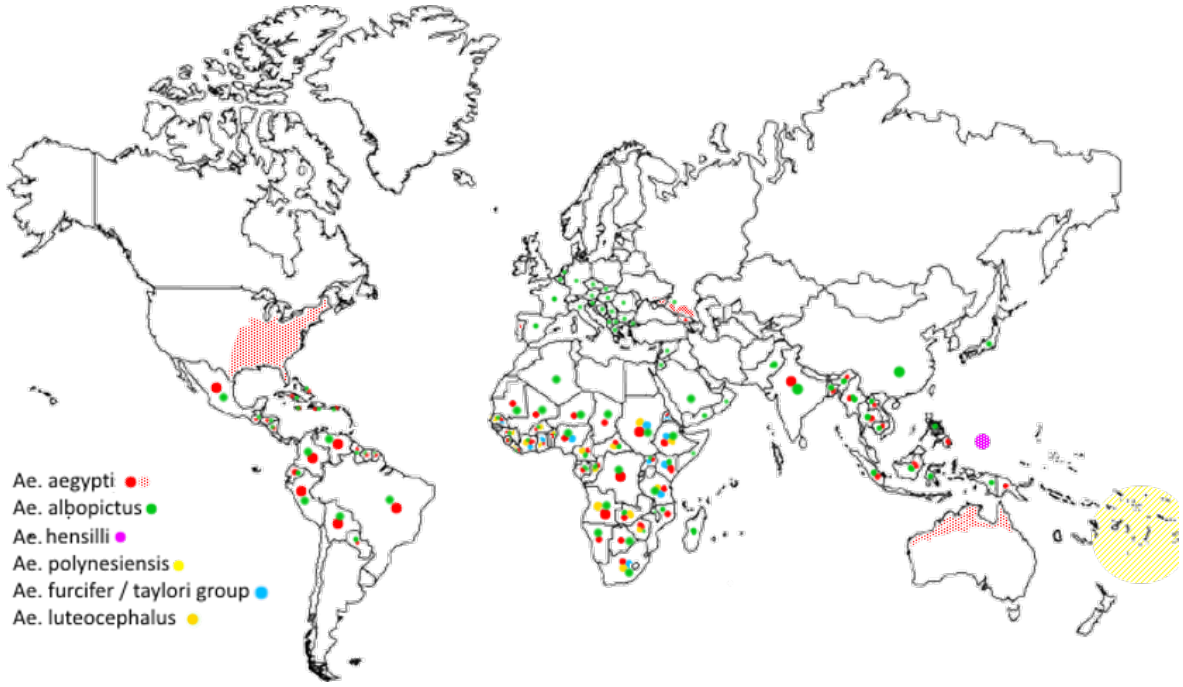

Figure 2. Geographical distribution of main vectors of Zika Virus. Aguilar-Cabezas (2016)

2.2. *Ae. albopictus* (Skuse,1895)

This species is of particular interest in the transmission of the four serotypes of dengue virus, eastern equine encephalitis [21] and Japan equine encephalitis [22], as well as the Chikungunya [23] virus and the West Nile [24,25]. In addition, it has been documented that it can transmit the yellow fever virus, which is the bridge vector between the jungle and urban cycle of transmission.

2.2.1. Geographical Distribution

Ae. albopictus can be found in tropical, subtropical and temperate regions. It has spread from Asia and become established in areas of the South Pacific, Africa, Europe and in the decade of the 80 in the Americas [26,27]. *Ae. albopictus* has been located in other countries of America, including Brazil and Dominican Republic [27]. In South America, the first record of *Ae. albopictus* was done in Brazil in 1986 [27], where it has been widely distributed and has colonized 20 of the 27 states [28]. Other countries in South America where the presence of this species has been detected, chronologically, are Bolivia in 1995 [29], Colombia in 1998 [30] and, more recently, in Argentina [31] and Uruguay [32] in 2003, and in Venezuela in 2009. In Venezuela, it was first recorded as an invasive species of public health importance in the country [33].

2.1.3. Breeding

Ae. albopictus thrives in a wider range of water-filled breeding sites than *Ae. aegypti*, including coconut husks, cocoa pods, bamboo stumps, tree holes and rock pools, in addition to artificial containers such as vehicle tyres and plant pot saucers. This diversity of habitats explains the abundance of *Ae. albopictus* in rural as well as peri-urban areas and shady city parks [34].

2.1.4. Bionomics

It is a wild species that has adapted to urban environments. Females distribute oviposition in separate containers, a habit that contributes to the fast dispersion of the species. It is an anthropophilic mosquito also showing bestiality, with preference for birds [35]. Respect to altitude, *Ae. albopictus* was found in heights of 1800m., in the mountains of Thailand [36]. In the United States, higher altitudes reported correspond to 305m in New Alsace, Indiana [37]. The optimum water temperature for the development of *Ae. albopictus* appears to be 25°C; with this temperature the incubation period of the eggs is 2 days [38].

One of the major differences between North American populations of *Ae. albopictus* and *Ae. aegypti* is their distribution according to latitude. While populations of *Ae. aegypti* are limited to the southern regions of the United States, mainly because of its inability to tolerate very low temperatures, populations of *Ae. albopictus* have developed a photoinduced diapause in eggs, allowing them to colonize in temperate and northern latitudes. In addition, temperate strains of *Ae. albopictus* such as in North America, show resistance of eggs to cold, allowing species to survive suboptimal winter temperatures found in northern latitudes [39].

2.2. *Ae. hensilli* (Farner, 1945)

2.2.1. Geographical Distribution

This species is native to the island of Yap, composed of four closely associated islands, Marba, Gagil-Tomil, Maap, and Rumung, that lie within a fringing reef system [40]. It has also been incriminated as a vector of the Chikungunya virus [41]. In the South Pacific, *Ae. hensilli* was implicated in the spread of Zika virus on Yap Island in 2007 [42]. Roth et al [43] phylogenic analysis shows that virus strains on Yap are members of the Asian lineage and closely related to strains currently circulating in the Caribbean [40].

2.2.2. Breeding

Ae. hensilli breeds in coconut shells, tins, plastic containers, vehicle tyres, tree holes, canoes and metal drums [26]. Ledermann [41] indicated in the research "*Aedes hensilli* as a potential vector of Chikungunya and Zika viruses" that most prevalent containers with larvae or pupae were discarded cans, followed by coconut shells. Proportionally, containers including tires, tarps, floats, and bamboo had high percentages of immature larvae, but several of these container types were found only infrequently. Containers such as water barrels, used to collect rainwater, while proportionally fewer in number than other containers, were actually major contributors to mosquito production due to the sheer number of larvae and pupae present.

2.2.3. Bionomics

The four main islands of Yap are the remnants of old, metamorphic, high volcanic islands, with a current maximum elevation of 174 m. The climate of Yap is characterized by constant warm temperatures, heavy rainfall, and high humidity. Mean annual rainfall is 3,028 mm. The driest months are February, March, and April, with an average monthly precipitation of less than 180 mm [44]. The wettest season is July through October, when average monthly rainfall is 330 mm. Mean annual temperature is 27°C, with mean monthly variation of only 2°C. Daytime maximum and nighttime minimum temperatures differ by an average of 7°C. Mean relative humidity ranges from 79% to 85% [40].

2.3. *Aedes polynesiensis* (Marks, 1951)

The mosquito *Aedes polynesiensis*, a member of the *Aedes scutellaris* complex, is the primary vector in the South Pacific region of the *Wuchereria bancrofti* parasite, the causative agent of lymphatic filariasis (LF), (also known as Polynesian tiger mosquito) and an important vector of dengue [45]. *Ae. polynesiensis* was suspected to spread Zika virus in French Polynesia in 2013. [46], and is a suspected vector of Ross River virus in the Cook Islands.

2.3.1. Geographical Distribution

Ae. polynesiensis is only found in the South Pacific islands of Austral Islands, Cook Islands, Ellice Islands, Fiji Islands, Hoorn Islands, Marquesas Islands, Pitcairn Island, Samoa Islands, Society Islands, Tokelau Islands and Tuamotu Archipelago [47].

2.3.2. Breeding

Ae. polynesiensis uses domestic and natural containers with equal frequency.This species is semi-domestic with an extremely wide range of breeding places that includes tree holes, coconut shells and husks, various types of artificial containers, leaf axils, crab holes, banana stumps, cacao pods and canoes. This mosquito prefers tree holes, but not water-storing drums [48,49].

2.3.3. Bionomics

Females are primarily diurnal with biting peaks in the late afternoon and early morning [48]. In a study to assess the relative importance and distribution in Samoa indicates that Aedes polynesiensis was present in all villages. Slight invasiveness: it seems to be confined to a small area of the South Pacific. Biosecurity risk: moderate because of tropical habitat [49].

2.4. *Aedes* (Diceromyia) Furcifer / Taylori Group *(Edwards, 1913)*

The *Aedes* (Diceromyia) furcifer / taylori group was initially considered to be composed of two species: *Ae. taylori* and *Ae. furcifer* [50]. *Ae. furcifer* has been recently divided into *Ae. furcifer* ss. and *Ae. cordellieri* [51,52]. The three species are found in West, Central and South Africa, but only *Ae. furcifer* and *Ae. taylori* seem to be well established in West Africa and Central Africa. *Ae. cordellieri* is the only species of the group present in East Africa. These species share several bioecological characteristics [53].

Ae. furcifer is involved in the monkey-to-man and, to a lesser extent, man-to-man transmission of yellow fever Germain, Francy [50], a potential vector of dengue 2 [54], and a vector of Chikungunya viruses [56].

2.4.1. Geographical Distribution

Burkina Faso, Eritrea Ethiopia, Gambia, Ghana, Guinea Bissau, Ivory Coast, Kenya, Nigeria, Senegal, South Africa, Sudan, Tanganyika, Transvaal, Tanzania, Togo, Uganda [56].

2.4.2. Breeding

They are absent in forest areas and well represented in the savannah areas in open spaces. Their breeding sites are natural and include mainly tree holes, bamboo, fruit and so on. They are simioanthropophilic with a crepuscular peak in biting activity. *Ae. furcifer* is the only species of the group that has activity in villages bordering the forest environment. Such behavior confers to this species a very important role in domestic transmission cycles. *Ae. taylori* and *Ae. cordellieri* remain confined to the wild habitat [57].

2.4.3. Bionomics

Aedes furcifer/*cordellieri* is the only prevalent tree hole *Aedes* which feeds readily on monkeys and humans and is present through the summer until the onset of winter [57].

2.5. *Ae. luteocephalus* (Newstead,1907)

It is a mosquito species of the Culicidae family zoogeographically found en Ecuatorial Africa. *Ae. luteocephalus* is another species of the subgenus stegomyia, morphologically similar to the *Ae. africanus* group species.

It is a vector of dengue virus, yellow fever, Chikunguya epidemic arthritis and Zica fever. It is one of the major

vectors of yelow fewer in West Africa, which has been confirmed in various outbreaks (Lee & Moore, 1972).

Both *Ae. furcifer* and Ae. luteocephalus involve a sylvan transmission cycle of CHIKV between mosquitoes and wild primates, limited to tropical Africa, and epidemic transmission of the virus is sustained though infection of the mosquitoes *Ae. aegypti* and *Ae. albopictus* in urban and peridomestic environments [57] (Jupp and McIntosh 1990, [48] Diallo *et al*. 1999).

2.5.1. Distribution

Angola, Benin, Burkina Faso, Camerún, República Centroafricana, R.D. Congo, Costa de Marfil, Guinea, Etiopía, Ghana, Liberia, Nigeria, Senegal, Sierra Leona, Sudáfrica, Sudán, Tanzania, Zambia y Zimbabwe [56].

2.5.2. Breeding

The preferred larval habitats are tree holes and rot holes with bamboo. Bamboo stems and artificial containers are also utilized. Females have been captured while biting man [59,60].

2.5.3. Bionomics

It is simioanthropophilic, has a crepuscular behaviour and takes blood meals at the canopy, but occasionally bites on the ground. The species are abundant in forest habitat and may be present in very rare situations in the villages surrounding the forest.

3. Conclusion

Further studies are of the utmost importance to address the bionomics, ecology and behavior of less common species involved in the transmission of Zika virus, such as environmental variables, food preferences, different types of breeding, flight range, and other factors that could facilitate their dispersion.

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