

Review Article

A review on the mosquitoes with epidemiological concern in Morocco: geographic distribution, bio-ecology, and public health risks

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Abstract. The spread and establishment of invasive mosquitoes (Diptera: Culicidae) have drawn increasing attention in recent years, particularly the introduction of *Aedes albopictus*. In Morocco, multiple species occur and are recognized as vectors or potential vectors of several arboviruses (dengue, chikungunya, Rift Valley fever virus, and West Nile virus). Some species have been established for decades (*Ae. aegypti*, *Ae. vexans*, *Ae. caspius*, *Ae. detritus*, and *Culex pipiens*), while others are invasive newcomers (*Ae. albopictus*). This review provides an overview on each mosquito species, their geographic distribution (from 1916 to 2025), bio-ecology, involvement in arbovirus transmission, and emphasizes the need for increased monitoring efforts and control.

Keywords: Vector-borne diseases, Arthropod-borne viruses, Public health, Emergence, Maps

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Introduction

Vector-borne diseases have a devastating impact on animal and human health. According to the World Health Organization (WHO), vector-borne diseases account for more than 17% of all infectious diseases and cause more than one million human deaths per year (Fournet *et al.*, 2018). These diseases are transmitted between humans or from animals to humans via a competent vector organism. The most common vectors are bloodsucking arthropods (mosquitoes, ticks, flies, etc.) that ingest pathogens (viruses, parasites, etc.) during a blood meal from an infected host and then transmit them to a new host with a subsequent blood meal (Mayer *et al.*, 2017).

In recent years, vector-borne diseases, particularly those caused by mosquito-borne arboviruses, have experienced a worrying resurgence. Since their discovery, the number of arboviruses has continued to increase and expand geographically (Gould *et al.*, 2017). Current data reports more than a hundred different types of mosquito-borne viruses are involved in human pathologies such as chikungunya (CHIKV), dengue (DENV), Zika (ZIKV), Rift Valley fever (RVFV), and West Nile virus (WNV) (Braack *et al.*, 2018). The frequency and intensity of arbovirus outbreaks are expected to increase throughout the 21st century due to globalization, human population growth, climate change, and the availability and expansion of mosquito vectors (Flores & O'Neill, 2018). It is estimated that more than 82% of the world's population already lives in areas at risk of at least one arbovirus disease, with more than half at risk of two or more (Golding *et al.*, 2015). The risk of infection is particularly high in areas where *Aedes* and *Culex* mosquitoes proliferate due to the presence of favorable habitats and close contact with humans (Liang *et al.*, 2015). Morocco's mosquito inventory includes 43 species belonging to seven genera and 18 subgenera. The most represented genera are *Aedes* and *Culex* (12

species), followed by the genera *Anopheles* (nine species) and *Culiseta* (5 species). The genera *Coquillettidia* and *Uranotaenia* are represented by only two species and the genus *Orthopodomyia* by only one species (Trari, 2017). Of these 43 species, six are implicated as the main vectors of many arboviruses: *Ae. aegypti* (Linnaeus, 1762), *Ae. albopictus* (Skuse, 1895), *Ae. vexans* (Meigen, 1830), *Ae. caspius* (Pallas, 1771), *Ae. detritus* (Haliday, 1833), and *Cx. pipiens* (Linnaeus, 1758). With increasing globalization and the landscape of emerging pathogens constantly changing, knowledge of potential vector species, their current geographic distribution, and their involvement in arbovirus transmission is essential for a thorough understanding of human health risk and for preparation for future threats.

Important mosquito-borne arboviruses detected in Morocco

Dengue virus

(DENV; Family: Flaviviridae, genus: Flavivirus) is an arbovirus ubiquitous in the tropics that is vectored to humans through the bites of infected female mosquitoes, mainly *Ae. aegypti* (Apodaca-Medina *et al.*, 2018). Other species of the genus *Aedes* may also act as vectors, such as *Ae. albopictus*, *Ae. vittatus* (Bigot, 1861), *Ae. polynesiensis* (Marks, 1951), *Ae. scutellaris* (Walker, 1859), and *Ae. japonicus* (Theobald, 1901) (Mavale *et al.*, 1992; Carrington & Simmons, 2014; Brustolin *et al.*, 2018). Dengue virus is transmitted both in urban areas (human transmission cycle) and in forest/rural areas (sylvatic transmission cycle). These two cycles of transmission are different from an ecological and Evolutionary point of view. In urban areas, transmission occurs between humans, while in forested areas, transmission occurs between non-human primates with occasional spillovers into human populations (Carrington & Simmons, 2014).

The global incidence of dengue and serious clinical presentations have increased significantly over the past five decades. Approximately 50 to 200 million infections, 500,000 episodes with serious complications, and more than 20,000 dengue-related deaths occur each year (Guo *et al.*, 2017). Moreover, this disease has become endemic in more than 100 countries in Africa, the Americas, Eastern Mediterranean, Southeast Asia, and Western Pacific. It is estimated that up to 3.6 billion people now live in areas where dengue virus can be transmitted (Brady *et al.*, 2012). In Morocco, two imported cases of dengue fever were reported in 2017 in two patients, both travelling from the Ivory Coast, a Moroccan and an Ivorian who were staying in Abidjan during a 2017 outbreak (Bajjou *et al.*, 2018). A field-collected strain of *Ae. albopictus* from Morocco in 2016 was experimentally infected with dengue DENV and showed moderate transmission potential, with virus detected in saliva at day 14 post-infection. These results indicate that local DENV transmission by invasive *Ae. albopictus* in Morocco is a plausible risk (Amraoui *et al.*, 2019).

Chikungunya

(CHIKV; Family: Togaviridae, genus: Alphavirus) is an arbovirus that causes debilitating arthritis and arthralgia in infected humans (Vu *et al.*, 2017). CHIKV has caused explosive epidemics across multiple continents, including major outbreaks in the Indian Ocean (2005-2006), India (2006), and the Caribbean, demonstrating its rapid global expansion from African origins (Henry *et al.*, 2017). Similar to dengue, chikungunya virus is maintained in a sylvatic transmission cycle that occurs between various forest *Aedes* mosquitoes (*Ae. taylori* (Edwards, 1936), *Ae. luteocephalus* (Newstead, 1907), *Ae. africanus* (Theobald, 1901) and *Ae. neoafricanus* (Cornet, Valade & Dieng, 1978)) and animal reservoirs, with non-human primates being the main reservoir host (Coffey *et al.*, 2014). Urban transmission is primarily mediated by *Ae. aegypti* and *Ae. albopictus* mosquitoes and occurs in a human-mosquito-to-human transmission cycle. While enzootic forest transmission of CHIKV is well-established in Africa, outbreaks in Asia have been primarily attributed to urban transmission (Weaver *et al.*, 2020). In Morocco, only one imported case of chikungunya was reported in 2017. The case was a 37-year-old woman who returned to Morocco after 18 months in Dhaka Bangladesh where she acquired the infection (Bajjou *et al.*, 2017). The same Moroccan field-collected *Ae. albopictus* strain (2016), that showed moderate DENV transmission capacity, demonstrated high competence for CHIKV, with infectious virus detected in saliva as early as 3 days post-infection (Amraoui *et al.*, 2019).

Rift Valley Fever virus

(RVFV; Family: Phenuiviridae, genus: *Phlebovirus*) is a long-recognized disease of humans and domesticated livestock in sub-Saharan Africa but has crossed several barriers including Arabian Peninsula, and some Indian Ocean Islands (Sumaye *et al.*, 2019; Ngoshe *et al.*, 2020). Humans and livestock (cattle, sheep, goats, and camels) are primarily exposed to the virus through the bite of infected mosquitoes, particularly those from the genera *Aedes* and *Culex* (Tantely *et al.*, 2015). The virus still circulates at common borders with Mauritania (southern Morocco) where multiple outbreaks occurred in 1987, 1993, 2003, 2010, and 2012, resulting in

numerous animal deaths as well as human fatalities (Caminade *et al.*, 2014). The Moroccan Veterinary Services conducted a serological study on 100 camels in 2010, and 50 of them tested positive for RVF-specific antibodies by competitive ELISA, which was later verified by virus-neutralization (El-Harrak *et al.*, 2011).

West Nile virus

(WNV; Family: Flaviviridae, genus: *Flavivirus*) was initially identified in 1937 in the West Nile district of Northern Uganda from a febrile patient (Smithburn *et al.*, 1940). Since then, the virus has been recorded in over 83 countries throughout the world, making it one of the most widely spread arboviruses (Chancey *et al.*, 2015; Al-Jabi, 2017). A cycle of transmission between mosquitoes and birds maintains the virus in nature, whereas people and horses have been accidentally infected, but are considered dead-end hosts since they do not contribute significantly to its illness spread. The main amplifying hosts and vectors that significantly contribute to the re-emergence and worldwide spread of WNV are birds and mosquitoes (*Culex* and *Aedes*) (Komar *et al.*, 2003; Levine *et al.*, 2017; Soltész *et al.*, 2017; Rochlin *et al.*, 2019). Morocco has experienced multiple outbreaks of WNV. The first one was reported in 1996 in Benslimane region and resulted in the death of 42 horses (among 94 equine confirmed cases) and one-person (Benjelloun *et al.*, 2017). In the second incident, WNV spread among horses (5 deaths out of 9 equine cases) in September and October of 2003 in three locations: Mograne, Ameer Seflia, and Ouled Slama (Schuffenecker *et al.*, 2005). The virus returned to the central and northwest regions (Mohammedia, Casablanca, Benslimane, and Khemisset) in 2010 and resulted in the death of eight horses and 17 confirmed cases (out of 111 suspected cases) (Benjelloun *et al.*, 2016). Wild birds serosurvey (Figueroa *et al.*, 2009), WNV-specific antibodies detection in camels and humans (El-Harrak *et al.*, 2011; El Rhaffouli *et al.*, 2012; Harrak *et al.*, 2016), laboratory susceptibility and natural infection of *Cx. pipiens* (Amraoui *et al.*, 2012a; Assaid *et al.*, 2020), all provided evidence that WNV was widely circulating in Morocco.

Important mosquitoes found in Morocco

Aedes aegypti

Aedes aegypti (Linnaeus, 1762) is commonly referred to as the yellow fever mosquito (Reinert *et al.*, 2004). Native to sub-Saharan Africa, its ancestral form was a sylvatic zoophilic mosquito called *Ae. aegypti formosus* which exclusively bit animals and laid eggs in tree holes (Powell & Tabachnick, 2013). *Aedes aegypti*, the domestic form, was introduced into the new world from Africa during the seventeenth century by ships and the slave trade (Brown *et al.*, 2014). Since then, the species has spread globally. Currently, it is distributed in the tropical and subtropical regions of Africa and South America, the southeastern United States, the Middle East, Southeast Asia, the Pacific Islands, India, and northern Australia (Medlock *et al.*, 2015).

Until the first half of the 20th century, *Ae. aegypti* was previously established in southern Europe and the Mediterranean basin (Schaffner & Mathis, 2014). It had been reported in Azerbaijan, Cyprus, France, Georgia, Greece, Italy, Malta, Portugal, southern Russia, Sardinia, Spain, Turkey, Algeria, Egypt, Libya, and Morocco (Schaffner & Mathis, 2014; Medlock *et al.*, 2015). More than 50 years later and for unknown reasons, it has disappeared from most of these countries and was even presumed probably extinct (Kotsakiozi *et al.*, 2018). *Aedes aegypti* was reintroduced in 2001 in the Sochi region of Russia and then in 2005 on the Portuguese island of Madeira (Iunicheva Iu *et al.*, 2008; Ibañez-Justicia *et al.*, 2017; Abozeid *et al.*, 2018; Akiner *et al.*, 2019; Seixas *et al.*, 2019). In Morocco, *Ae. aegypti* was once very common throughout the Moroccan coastline (Fig. 1), especially in the cities of Rabat and Casablanca (Vialatte, 1923). This species has also been found in Tangier (Charrier, 1924), Salé, and Marrakech (Gaud, 1953). The last available notification documenting its presence in Morocco was in 1997, when its larvae were collected in the Sebkha Chemaia, central Morocco (Vialatte, 1923; Charrier, 1924; Gaud, 1953; Handaq, 1998).

Larval habitats

Unlike its ancestral form that laid eggs in tree holes, *Ae. aegypti* preferentially deposits its eggs in artificial larval habitats of anthropogenic origin. Most often, females do not lay their entire batch of eggs in one shot and one place, but rather choose to lay a few eggs in several separate nests (skip-oviposition), which ensures greater dispersion of offspring and reduces competition (Oliva *et al.*, 2014; Ferede *et al.*, 2018). The larval habitats are of various kinds: used tires, buckets, small plastic containers, barrels, flower pots, saucepans, jars, and even abandoned school cabinets (Ferede *et al.*, 2018). This diversity of larval sites used is a testament to its great adaptability to different environmental conditions.

Trophic behavior

Aedes aegypti mosquitoes prefer mammalian hosts and will preferentially feed on humans, even in the presence of alternative hosts (Jansen & Beebe, 2010; Cebrián-Camisón *et al.*, 2020). It prefers to enter human dwellings that offer opportunities for searching a potential target. Females appear to bite during day and night, with peak activity at dawn and dusk in warm regions (Captain-Esoah *et al.*, 2020).

Medical importance

Aedes aegypti is the main vector of yellow fever virus (YFV), DENV, CHIKV, Mayaro (MAYV), Uganda S (UGSV), and ZIKV (JPT, 1958; Lourenco-de-Oliveira *et al.*, 2002; Li *et al.*, 2012; Ferreira-de-Brito *et al.*, 2016; Guerbois *et al.*, 2016; Richard *et al.*, 2016; Costa-da-Silva *et al.*, 2017; Apodaca-Medina *et al.*, 2018; Cevallos *et al.*, 2018; da Costa *et al.*, 2018; Magalhaes *et al.*, 2018; Main *et al.*, 2018; Kantor *et al.*, 2019).

Aedes albopictus

Aedes albopictus (Skuse, 1895) is commonly referred to as the Asian tiger mosquito (Reinert *et al.*, 2004; Faraji & Unlu, 2016). It has experienced recently a dramatic global expansion facilitated by human activities, particularly the international trade in used tires and bamboo (Reiter, 1998; Hofhuis *et al.*, 2009; Bennett *et al.*, 2019). This, combined with the passive transport of eggs supporting desiccation via public and private transport, has resulted in its wide global distribution. It is now ranked among the 100 most important invasive species in the world (Amraoui *et al.*, 2019).

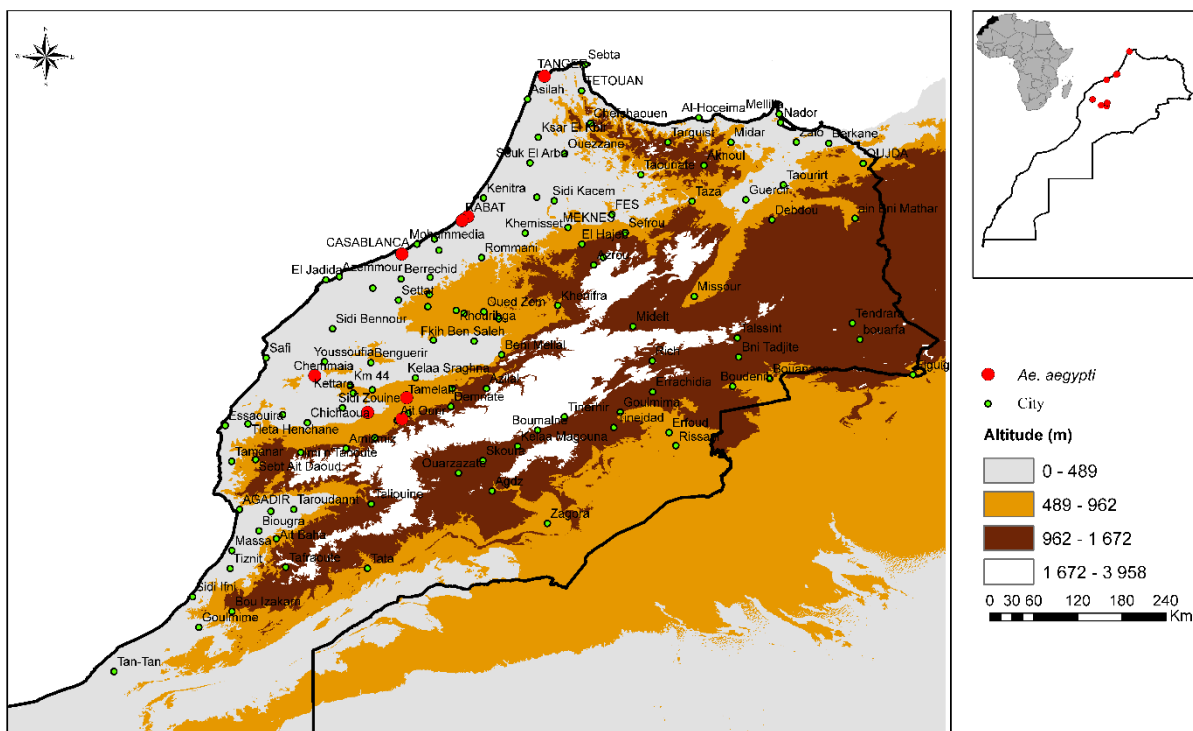


Fig. 1. Distribution of *Ae. aegypti* in Morocco

Endowed with high plasticity allowing it to adapt to various ecological conditions, this species has established itself in more than 100 countries on five continents. It has been reported so far in 25 different countries in Europe, the Middle East (Azari-Hamidian *et al.*, 2024), the Arabian Peninsula (Saudi Arabia, Yemen), South America, Central America, North America, Australia, on many islands in the Pacific and Indian Oceans, and in Africa (Cameroon, Central African Republic, Equatorial Guinea, Gabon, Madagascar, Nigeria, South Africa) (Medlock *et al.*, 2015). In Maghreb countries, this mosquito has been reported in Algeria (2010-2018), Tunisia (2018), and Morocco in Rabat in 2016 (Izri *et al.*, 2011; Benallal *et al.*, 2016; Bennouna *et al.*, 2017; Bouattour *et al.*, 2019). *Aedes albopictus* is believed to be underestimated in Morocco (Fig. 2) because it has a much larger distribution in the country, especially in the urban areas of the Orient and North, where the trade in used tires imported from abroad has been thriving in recent years.

Larval habitats

Aedes albopictus tends to proliferate in small patches of water, often artificial and surrounded by vegetation. It can thrive in cemetery flower pots, bird baths, buckets, jars, cement tanks, cans, and discarded bottles, etc (Unlu *et al.*, 2013). However, used tires remain the most frequently colonized type of sites, as they are often stored outdoors and effectively collect and retain rainwater for a long time (Abílio *et al.*, 2018; Stefopoulou *et al.*, 2018).

Trophic behavior

Although *Ae. albopictus* preferentially bites mammals (including humans), females can also feed on most groups of vertebrates, both cold-blooded and warm-blooded, including reptiles, birds, and amphibians (Kamgang *et al.*, 2012; Faraji *et al.*, 2014; Muhammad *et al.*, 2020).

Medical importance

Aedes albopictus is the world's most important vector of arboviruses. It has been found capable of transmitting up to 39 viruses: Arumowot (AMTV), Bujaru (BUJV), Bussuquara (BSQV), Cache Vallée (CVV), Chandipura (CHPV), Chilibre (CHIV), Eastern Equine Encephalomyelitis (EEEV), Getah (GETV), Icoaraci (ICOV), Ilheus (ILHV), Itaporanga (ITPV), Jamestown Canyon (JCV), Japanese Encephalitis (JEV), Karimabad (KARV), Keystone (KEYV), Kokobera (KOKV), Kunjin (KUNV), La Crosse (LACV), Mayaro (MAYV), Oropuche (OROV), Orungo (ORUV), Pacui (PACV), Potosi (POTV), Rift Valley Fever Virus (RVFV), Ross River (RRV), Salehabad (SALV), San Angelo (SA), St. Louis Encephalitis (SLEV), Tensaw (TENV), Trivittatus (TVTV), UGSV, Urucuri (URUV), Usutu (USUV), Venezuelan Equine Encephalitis (VEEV), WNV, YFV, DENV, CHIKV, and ZIKV (Pereira-Dos-Santos *et al.*, 2020).

A study tested its vector competence by infecting a local strain with DENV, CHIKV, ZIKV and YFV, revealing high transmission potential for CHIKV and lower but significant transmission for DENV, ZIKV, and YFV. Virus detection in mosquito saliva occurred as early as day 3 (CHIKV), day 14 (DENV, YFV), and day 21 (ZIKV) post-infection. These findings indicate a high risk of local arbovirus transmission by *Ae. albopictus* in Morocco (Amraoui *et al.*, 2019).

Aedes vexans

Aedes vexans (Meigen, 1830), or the inland floodwater mosquito, is widely distributed throughout the Holarctic region, Eastern Europe, North America, North Africa, the Arabian Peninsula, parts of East Asia as well as the Australasian and Oceanic Islands. (Birnberg *et al.*, 2019; Parry *et al.*, 2020). In Morocco, the oldest citation of this species was by Gaud in 1947 in El-Khémisset and Sidi Allal Tazi (Gaud, 1947). The species was subsequently reported on the Casablanca coast (88), el Jadida, Zemamra, and Chemaia. Then in Fez and finally in Meknes (Fig. 3) (Gaud, 1947; Metge, 1986; Handaq, 1998; El Ouali Lalami A., 2010; Handaq & Blenzar, 2017).

Larval habitats

This species thrives mainly in floodplains, rivers, and lakes. Like most floodwater mosquitoes, *Ae. vexans* lay their dessication-resistant eggs near temporary or semi-permanent ponds predisposed to seasonal flooding. Their diapause eggs survive long periods of drought and hatch massively after flood episodes (Becker *et al.*, 2020).

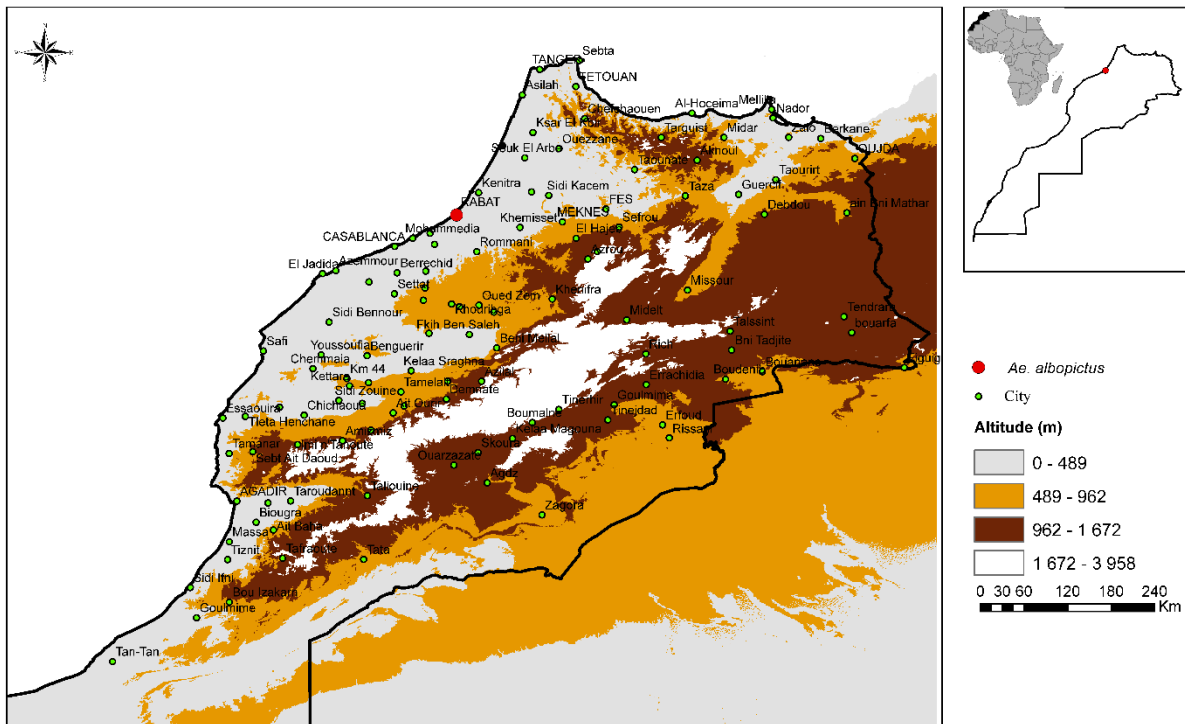


Fig. 2. Distribution of *Ae. albopictus* in Morocco

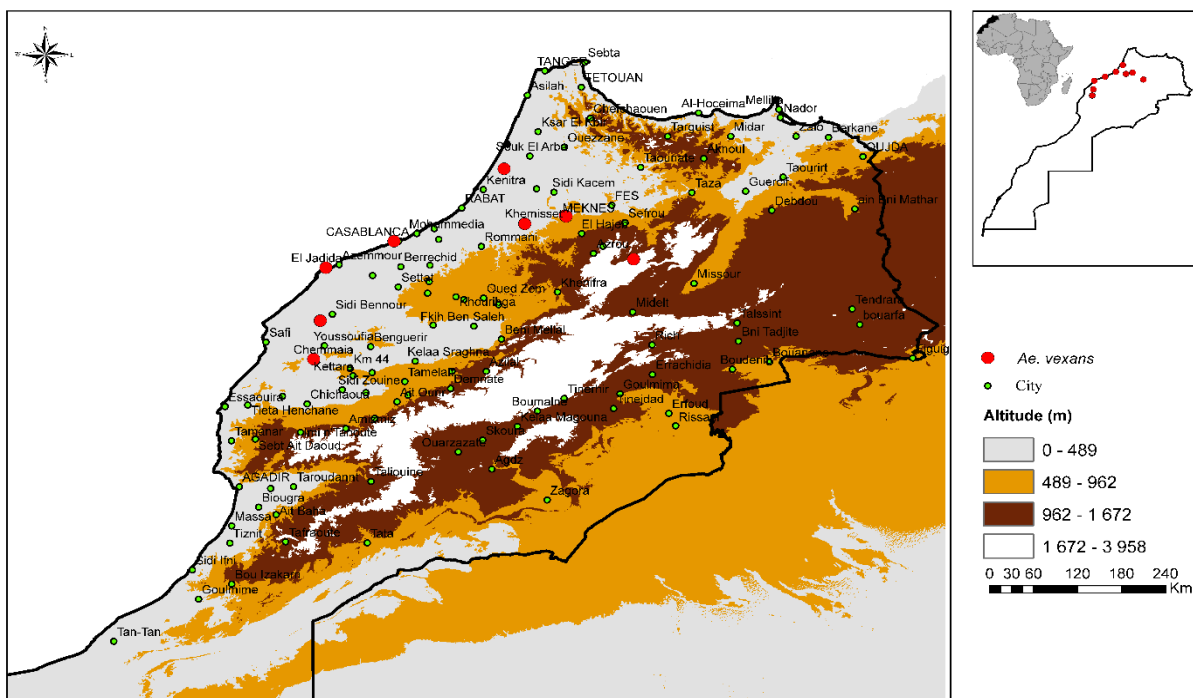


Fig. 3. Distribution of *Ae. vexans* in Morocco

Trophic behavior

Females are aggressive with low host specificity in mammals and humans, which is relevant for the potential transmission of pathogens. In Europe, female bite rates are so high that staying outdoors becomes virtually impossible, especially during the evening hours (Becker & Lüthy, 2017).

Medical importance

In North America and Europe, several arboviruses, such as WNV, Snowshoe hare virus (SSHV), Jamestown Canyon virus (JCV) (Gligic & Adamovic, 1976; Medlock *et al.*, 2017; Sang *et al.*, 2017), Batai virus (BATV) (Elizondo-Quiroga *et al.*, 2018; Scheuch *et al.*, 2018; Karliuk *et al.*, 2021) were isolated from *Ae. vexans*. In Africa, it is considered one of the main vectors of the RVFV (Miller *et al.*, 2002; Ndiaye *et al.*, 2016; Sang *et al.*, 2017).

Aedes caspius

Aedes caspius (Pallas, 1771) is a species with a very wide Palearctic distribution; extending from Europe to Central Asia. It is also well-established in Russia and the Middle East (Robert *et al.*, 2019; ECDC, 2020). In the European continent, its presence generates mainly nuisance especially around the Mediterranean along the coast. It has been reported in Italy (Veronesi *et al.*, 2012), France (Balenghien *et al.*, 2008; Carron *et al.*, 2008), Belgium (Boukraa *et al.*, 2015), Spain (Gutierrez-Lopez *et al.*, 2019), etc. In Morocco, it occurs both in coastal wetlands and in the interior of the country (Fig. 4) (Handaq, 1998; Handaq & Blenzar, 2017).

Larval habitats

The female of *Ae. caspius* lays eggs on moist soil, at the base of clumps of vegetation, the watering of which causes the eggs to hatch. Larvae develop in most cases in brackish water but can also be found in freshwater (Bellini *et al.*, 1997).

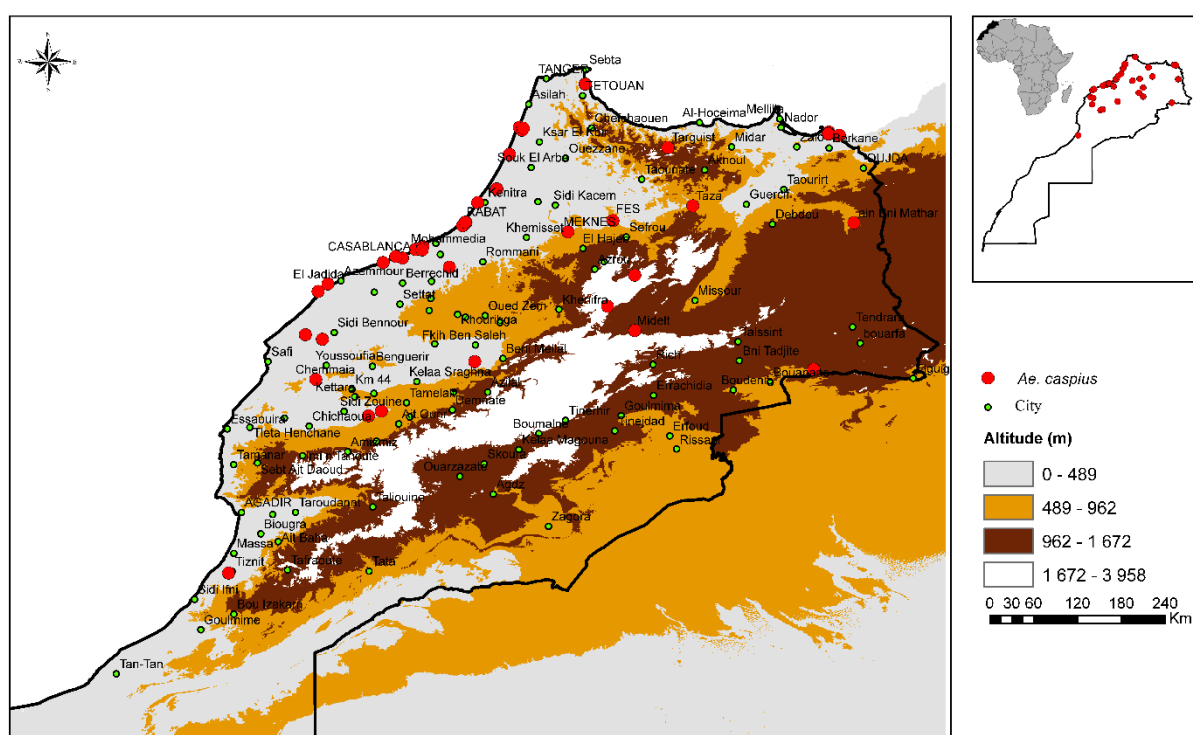


Fig. 4. Distribution of *Ae. caspius* in Morocco

Trophic behavior

Aedes caspius is an anthropophilic species preferably known to bite during the day and night, with a peak of activity at dusk. It usually feeds aggressively inside and outside homes (Veronesi *et al.*, 2012).

Medical importance

Most studies dealing with the vector role of this mosquito concern arboviruses and more specifically the Tahyna virus (Pilaski & Mackenstein, 1985), WNV (Orshan *et al.*, 2008; Ergunay *et al.*, 2014), and RVFV (Turell *et al.*, 1996; Tantely *et al.*, 2015). It may also be involved in the transmission of Sindbis (Lundstrom, 1999) and Usutu viruses (Cook *et al.*, 2018).

Aedes detritus

Aedes detritus (Haliday, 1833) is a Palearctic species that occurs throughout the European coast, the Baltic Sea as well as the Atlantic Ocean, and around the Mediterranean basin. It is a common species that is more abundant in southern and dry regions, i.e., in the United Kingdom (Blagrove *et al.*, 2016), Italy (Mancini *et al.*, 2017), Belgium (Boukraa *et al.*, 2015), France (Brenques *et al.*, 2014) and Spain (Ruiz-Arrondo *et al.*, 2019). In addition, it has a dispersed distribution in the inland saline areas of Europe, North Africa, and Southwest Asia.

In North Africa, it was detected in Egypt (Abdel-Hamid *et al.*, 2011), Tunisia (Ben Ayed *et al.*, 2019), Algeria (Metge & Hassaïne, 1998), etc. In Morocco, *Ae. detritus* is very well represented in coastal areas (Fig. 5), where they are found on a fairly regular strip from Tangier to Tantan (Atlantic coast), and on a less regular strip from Tangier to Saïdia (Mediterranean coast) (Trari, 2017).

Larval habitats

It is a typically halophilic species and the larvae are found almost exclusively in habitats with an exceptionally high salinity content; and are found only occasionally in freshwater (Blagrove *et al.*, 2016). Larvae can be found in semi-permanent ponds in open marshes and drainage channels or stagnant lagoons, with little aquatic vegetation. They are sometimes found with larvae of *Ae. caspius*, but most often, due to tolerance to extreme salinity, the species occurs alone in its aquatic habitats and does not co-occur with other species (Becker *et al.*, 2020).

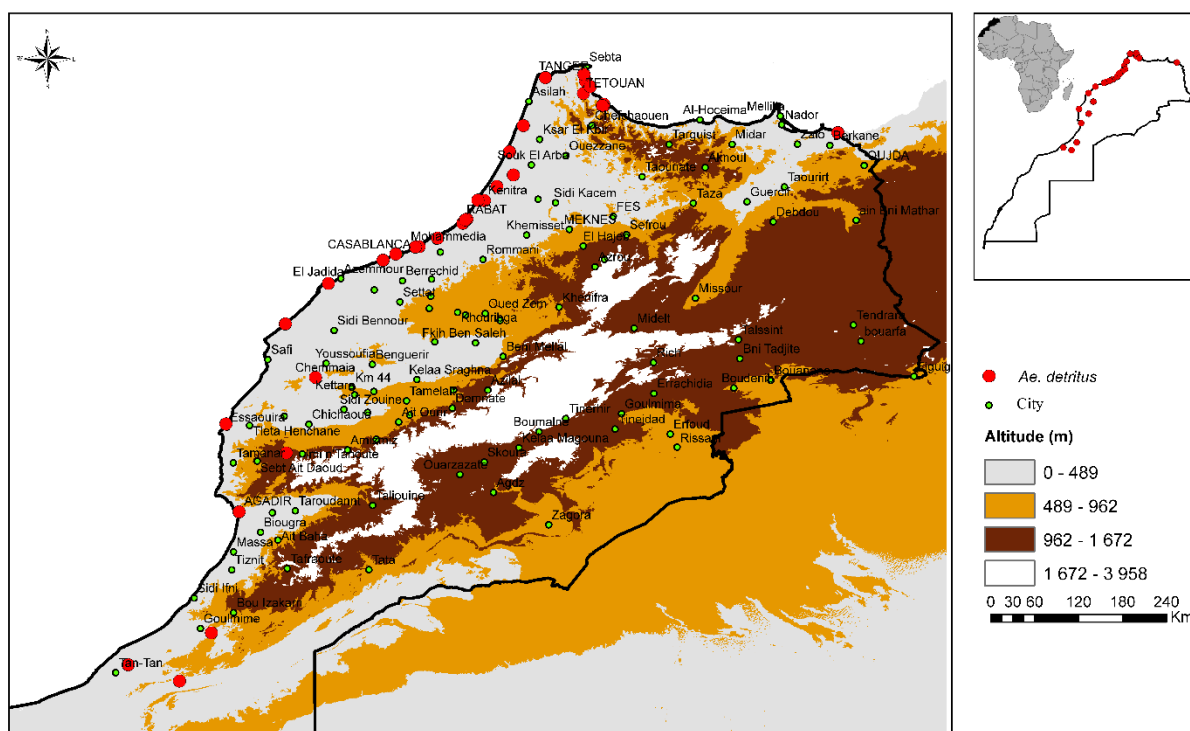


Fig. 5. Distribution of *Ae. detritus* in Morocco

Trophic behavior

Females are aggressive, persistent and easily attack humans, often in large numbers. They can feed during the day but are mainly active at dusk. *Aedes detritus* is a typical exophilic species that enters buildings only occasionally. Having a large flight capacity, they can travel more than 10 km to fetch their blood meal and thus constitute a significant nuisance at a great distance from emergence areas (Becker *et al.*, 2020).

Medical importance

Aedes detritus is a competent vector for ZIKV transmission, JEV, WNV, and RVFV (Vazeille *et al.*, 2008; Mackenzie-Impoinvil *et al.*, 2015; Tantely *et al.*, 2015; Blagrove *et al.*, 2016; Lumley *et al.*, 2018; Blagrove *et al.*, 2020).

Culex pipiens

In temperate regions, especially in the Mediterranean basin, *Cx. pipiens* (Linnaeus, 1758) is recognized as one of the most widespread cosmopolitan species (Amraoui *et al.*, 2012a; Brugman *et al.*, 2018). It is also found in temperate regions of Africa, Asia, Australia, Europe, and North and South America. *Culex pipiens* exists in two morphologically identical forms or biotypes, the *pipiens* form and the *molestus* form (Farajollahi *et al.*, 2011). The *pipiens* form is anautogenous, eurygamous (mates in the open air), and enters diapause during the winter (heterodynamic). The *molestus* form is autogenous, stenogamous (can mate in confined spaces) and remains active during the winter period (homodynamic). In Morocco, *Cx. pipiens* is a very common and ubiquitous species (Fig. 6) (Amraoui *et al.*, 2012b; Bkhache *et al.*, 2016; Aboulfadl *et al.*, 2020).

Larval habitats

Larvae of *Cx. pipiens* can be found in temporary or semi-permanent water sources, ponds with vegetation, rice fields, along rivers, in flood-prone areas, in puddles and ruts, sometimes even in water-filled tree holes (Müller *et al.*, 2012; Liu *et al.*, 2019; Becker *et al.*, 2020). They are also frequently present in artificial water bodies, such as flooded cellars, construction sites, road drains and pits, water barrels, metal tanks, ornamental ponds, and any type of container (Becker *et al.*, 2020). They can thrive in clear water but also in water polluted by organic matter (wastewater), and can even tolerate a small amount of salinity (Kengne *et al.*, 2019; Marini *et al.*, 2020).

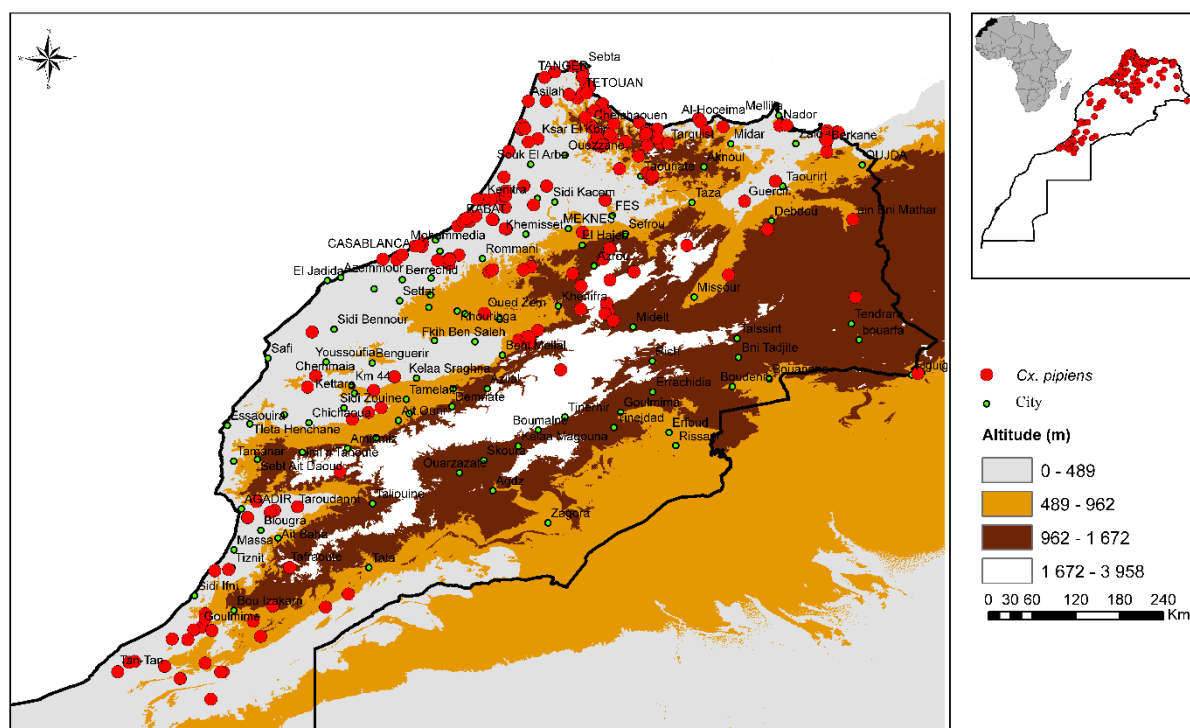


Fig. 6. Distribution of *Cx. pipiens* in Morocco

Trophic behavior

Females bite all warm-blooded vertebrates at night and eat their meals mostly indoors. *Culex pipiens* mosquitoes bite humans, but can also bite mammals (horses) and birds (Becker *et al.*, 2020). The *pipiens* form

feeds preferably on birds while the *molestus* form mainly on mammals (Amraoui *et al.*, 2012b; Shahhosseini *et al.*, 2018).

Medical importance

Culex pipiens is a competent vector of several pathogens infecting animals and humans, including WNV (Meegan *et al.*, 1980; Calzolari *et al.*, 2010; Mavridis *et al.*, 2018). In 2012, several populations of *Cx. pipiens* from different distinct habitats (urban and suburban) in Morocco and other countries in the Maghreb region were experimentally infected with WNV and RVFV (Amraoui *et al.*, 2012a). About 69.2% of mosquitoes developed a disseminated Infection of RVFV and of these, 77.8% transmitted the virus through saliva. All mosquitoes developed a highly disseminated infection with and excreted infectious saliva.

Conclusion

Currently, mosquito-borne pathogens pose one of the greatest public health challenges. Knowledge of mosquitoes of Morocco, their geographical distribution, bioecology, as well as their involvement in the transmission of diseases is essential for a good understanding of the current risk and preparing for future threats. The epidemiology of arboviruses has undergone significant changes throughout the world over the past thirty years, in connection with the intercontinental dissemination of the main vector species *Ae. albopictus* and *Ae. aegypti*, favored by human activities and current climatic changes. *Aedes albopictus*, recently found in Algeria and in Morocco, is a mosquito that spreads rapidly and the epidemiological consequences of its invasion and establishment are disastrous and well known throughout the world. Since the current knowledge of the Moroccan distribution of these two vectors remains incomplete and scattered, monitoring of their establishment is highly recommended. The recent reporting of *Ae. albopictus* in Morocco and the increase in the number of international travelers to the country could be one of the determining factors in the establishment of an autochthonous transmission cycle of arboviruses.

Author's Contributions

Outammassine Abdelkrim: Conceptualizing, data curation, data analyzing, writing and reviewing the manuscript. **Daoudi Mohamed:** writing and reviewing the manuscript. **Loqman Souad:** supervision, writing, review and editing. **Zouhair Said:** supervision, conceptualization, writing - review and editing, project administration, resources.

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The authors declare that there is no conflict of interest regarding the publication of this paper.

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Review Article

مروری بر پشه‌های دارای اهمیت اپیدمیولوژیک در مراکش: توزیع جغرافیایی، زیست‌بوم‌شناسی و فطرات بهداشت عمومی

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چکیده: گسترش و استقرار گونه‌های مهاجم پشه (Diptera: Culicidae) بخصوص ورود گونه *Aedes albopictus* در سال‌های اخیر، توجه فزاینده‌ای را به خود جلب کرده است. در مراکش، گونه‌های متعددی از پشه‌ها وجود دارند که به عنوان ناقل یا ناقل بالقوه چندین آربوویروس (دنگو، چیکونگونیا، ویروس تب دره ریفت و ویروس نیل غربی) شناخته می‌شوند. برخی از گونه‌ها، دهه‌هاست که در این کشور مستقر شده‌اند (*Ae. aegypti*، *Ae. vexans*، *Ae. caspius* و *Culex pipiens*)، در حالی که برخی دیگر، مهاجمینی تازه وارد هستند (*Ae. albopictus*). نوشتار حاضر، مروری بر گونه‌های پشه در مراکش، پراکنش جغرافیایی آنها (از ۱۹۱۶ تا ۲۰۲۵)، زیست بوم‌شناسی و نقش آنها در انتقال آربوویروس ارائه می‌دهد و بر ضرورت افزایش تلاش‌های نظارتی و راهکارهای کنترل تأکید می‌کند.

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