Review Article

Aedes Mosquitoes of Iran: An Updated Review of Distribution and Medical Importance

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Abstract

Background: Mosquitoes of the genus *Aedes* are among the most important vectors of human and animal pathogens worldwide.

Methods: A comprehensive literature search was performed across both national and international scientific databases to identify studies concerning the taxonomy, distribution, ecology, biology and medical importance of *Aedes* species in Iran. The search encompassed all relevant publications available up to June 2026.

Results: To date, a total of 15 *Aedes* species have been reported in Iran, including *Aedes aegypti*, *Ae. albopictus*, *Ae. caspius* s.l., *Ae. vexans*, *Ae. geniculatus*, *Ae. flavescens*, *Ae. echinus*, *Ae. pulcritarsis*, *Ae. caballus*, *Ae. detritus*, *Ae. unilineatus*, *Ae. vittatus*, *Ae. leucomelas*, *Ae. asiaticus*, and *Aedes cinereus*. These species inhabit a wide range of ecological environments, from coastal salt marshes and floodplains to forest tree holes and man-made containers. Several species, particularly *Ae. aegypti* and *Ae. albopictus*, are of significant public health concern due to their established role as vectors of arboviruses. These mosquitoes are invasive members of the genus *Aedes*. Other species, including *Ae. caspius* s.l., *Ae. vexans*, *Ae. vittatus*, *Ae. caballus* and *Ae. unilineatus*, have also been implicated in the transmission of various viral and parasitic pathogens. Recent records of newly recognized species, such as *Ae. asiaticus* and *Ae. cinereus*, have further expanded the known diversity of *Aedes* mosquitoes in Iran.

Conclusion: Continued entomological surveillance, taxonomic studies, and ecological investigations are essential to improve understanding of species distribution and to strengthen preparedness for the emergence and spread of *Aedes*-borne diseases in the country.

Keywords: *Aedes*; *Aedes*-borne diseases; Arboviruses; Dengue fever; Invasive mosquitoes

Introduction

Mosquitoes belong to the family Culicidae, order Diptera. They are a large and abundant group found throughout the temperate and tropical regions of the world. This family includes 3,730 species and 41 genera, classified in two subfamilies: Anophelinae and Culicinae (1). Based on recent reports, 73 species and 8 genera from these two subfamilies have been documented in Iran (2).

The genus *Aedes*, belonging to the subfamily Culicinae, comprises approximately 1,255 species classified into 10 subgenera (3). Several species in this genus are of considerable medical importance, as they serve as highly efficient vectors for a variety of devastating human pathogens. The public health threat is most notably characterized by their ability to transmit critical arboviruses, including Dengue virus (DENV), Zika virus (ZIKV) and Chikungunya virus (CHIKV). While *Aedes* mosquitoes are naturally distributed in temperate and tropical regions globally, certain species have significantly expanded their ecological niches beyond their native habitats, driven by anthropogenic activities and changing environmental conditions (4, 5).

The genus *Aedes* comprises 15 species found in Iran, highlighting the ecological diversity of the region. Ongoing surveillance programs are actively monitoring for the presence of additional species with the aim of identifying any potential new additions (2). These mosquitoes inhabit a wide range of environments, from natural floodwater pools to artificial containers in urban settings. The establishment and potential expansion of invasive species, such as *Ae. aegypti* and *Ae. albopictus*, pose a growing risk of autochthonous transmission of the aforementioned viruses. This risk is further amplified by rapid urbanization and climate change, which alter vector distribution across Iran's diverse ecological zones, from the northern floodplains to the southern coastal regions.

This review aims to provide a comprehensive assessment of *Aedes* species reported in Iran, with particular emphasis on geographical distribution. It also examines their role in transmitting important arboviral diseases.

Materials and Methods

The databases that were searched included PubMed, Web of Science, Scopus, Google Scholar, IranMedex, Scientific Information Database (SID), reports from the Iranian Ministry of Health, and World Health Organization (WHO) reports. The primary search term was "*Aedes*" combined with the keyword "Iran". Additional searches utilized various combinations of keywords and MeSH terms such as "mosquito", "*Aedes* mosquitoes", "Culicidae", "mosquito fauna" and "arbovirus vectors". Species-specific searches were also conducted using the scientific names of all *Aedes* species recorded in Iran. Boolean operators (AND/OR) and truncation techniques were applied to refine the searches as needed. The search covered publications from the inception of the databases up to June 2026, with no language restrictions. Persian-language articles were included and translated where necessary.

Taxonomic nomenclature and species status were updated in accordance with the most recent checklist of Iranian mosquitoes (2).

Results

Aedes mosquitoes reported in Iran include both native and invasive species, with the composition varying by region. A review of the available literature reveals that 15 species of the genus *Aedes* have been documented in Iran to date. The *Aedes* fauna of the country comprises six subgenera: *Aedes, Aedimorphus, Dahliana, Fredwardsius, Ochlerotatus* and *Stegomyia*. Iranian *Aedes* species include *Aedes aegypti, Ae. albopictus, Ae. asiaticus, Ae. caballus, Ae. caspius* s.l., *Ae. cinereus, Ae. detritus, Ae. echinus, Ae. flavescens, Ae. geniculatus, Ae. leucomelas, Ae. pulcritarsis, Ae. unilineatus, Ae. vexans* and *Ae. vittatus*.

The recorded species exhibit diverse ecological characteristics, habitat preferences and geographic distributions within Iran (Fig. 1).

Aedes (*Aedes*) *cinereus* Meigen, 1818

Aedes cinereus is a slightly acidophilic species. Its larvae are commonly found in semi-permanent, partially shaded floodplain pools, along lake edge vegetation, and in forest ponds. Adults typically emerge later in the season compared to other mosquito species. The species is multivoltine, producing at least two generations annually, and it overwinters in the egg stage (6).

Adult females feed primarily on mammals and readily bite humans if given the opportunity. They are most active during dawn and dusk, often occurring in large numbers and causing considerable nuisance. During the daytime, adults rest in sparse vegetation and are rarely found in open, unshaded habitats. In many regions, *Ae. cinereus* forms dense populations and is considered a significant pest for people engaging in outdoor recreational activities in forested environments (6).

Aedes cinereus is found extensively throughout

the northern Holarctic region. In Europe, it has been reported in numerous countries, including Belgium, Estonia, Germany, Ireland, the Netherlands, Norway, Sweden and the United Kingdom. Its distribution also extends across northern parts of the United States, Canada and Alaska, as well as Central Asia, Kazakhstan, Siberia, the Russian Far East and other regions of North America (7). In Iran, *Ae. cinereus* was recorded for the first time in Guilan Province in 2024 (8).

The Tahyna virus (TAHV) has been repeatedly isolated from *Ae. cinereus*, suggesting its potential involvement in the natural transmission cycle of the virus in endemic areas (6). Also, Sindbis virus was isolated from this species (9). Gutsevich et al. (10) noted its role in the spread of tularemia through mechanical transmission. However, more research is essential to better understand its epidemiological significance and vector competence under different ecological conditions.

Aedes (Aedimorphus) vexans (Meigen, 1830) [*Aedimorphus vexans* (Meigen)]

Aedes vexans, often referred to as the floodwater mosquito, often sees its populations increase dramatically following rainfall and flooding events (11). The species is widely recognized as one of the most common nuisance mosquitoes in the world. It can become highly abundant after flooding, especially in open, sunlit environments, leading to significant discomfort for both humans and animals, and it often bites during the daytime (12).

Aedes vexans overwinters in the egg stage. Females deposit eggs individually on moist, unflooded soil above the water table in areas that are periodically inundated by rainfall, surface runoff, groundwater seepage, or tidal activity. These sites provide favorable conditions for embryonic development and are likely to experience future flooding (13–15). If flooding does not happen after oviposition, the eggs can remain viable for up to five years and usually undergo diapause during colder seasons (6).

The extensive global distribution of *Ae. vexans* is partly attributable to its ability to exploit a broad range of larval habitats. This species occupies a variety of habitats but is particularly common in rural and semi-natural environments. These habitats include temporary rain pools, surface waters, tire ruts and stormwater management facilities (such as retention, detention and infiltration ponds). Additionally, its larvae can be found in dredging sites, salt-marsh impoundments, streams, floodplains, flooded forests and the margins of semi-permanent marshes and swamps that periodically dry out. They have also been found in forest pools and virtually any type of temporary water body (16).

Aedes vexans is a highly dispersive mosquito species that can travel significant distances from its breeding sites. In Utah, USA, adults have been reported to disperse 5–8 miles from larval habitats, while in British Columbia migrations of up to 10 miles have been documented (17). Consequently, the nuisance caused by this species may extend far beyond its breeding areas (16).

Aedes vexans is a multivoltine species with an adult lifespan of 3–6 weeks in natural environments. Mating occurs in swarms formed by males shortly after sunset, and females typically lay 108–182 eggs per oviposition cycle (18, 19). Adult *Ae. vexans* feed primarily on floral nectar, while females require blood meals for egg development. This species is an opportunistic feeder that bites a wide range of vertebrate hosts, including birds, mammals and humans, often taking multiple blood meals per gonotrophic cycle. Host-seeking activity peaks at dusk, particularly shortly after sunset, enhancing its potential to transmit zoonotic pathogens (19–21).

Aedes vexans is commonly found throughout the Holarctic region and is thought to have originated in Eastern Europe (6). Its geographic range includes Africa (15), North America, southern Canada, and nearly the entire United States, with the exception of Hawaii (17).

Aedes vexans is the most prevalent *Aedes* species found in northern Iran (22–24). This species was found in Anzali of Guilan Province for the first time in Iran (25). It has been reported in various provinces across the country, including Ardebil (26), Bushehr (27), East Azerbaijan (28-30), Fars (31), Golestan (32), Guilan (33–37), Hormozgan (38, 39), Isfahan (40, 41), Kermanshah (42), Kurdistan (42, 43), Lorestan (44), Mazandaran (45, 46), Sistan and Baluchistan (27, 47–49), South Khorasan (27) and West Azerbaijan (50).

Aedes vexans is not only a nuisance species but also plays a significant role in transmitting various pathogens to both humans and animals. This species has demonstrated vector competence for at least 30 different arboviruses (51). It is a competent vector of *D. immitis* and filarial nematodes causing setariasis and is considered one of the major vectors of canine heartworm disease in central Michigan, USA (52, 53). Laboratory research has shown that it can transmit the western equine encephalitis virus (WEEV), Saint Louis encephalitis virus (St. Louis EV) and eastern equine encephalitis virus (EEEV) (54).

In Europe, *Ae. vexans* has been associated with the transmission of TAHV (55). It is recognized as a significant vector of Rift Valley fever virus (RVFV) in both Africa and Europe (56, 57). Because *Ae. vexans* readily feeds on both birds and mammals, it can act as a bridge vector, facilitating the transmission of West Nile virus (WNV) from avian reservoirs to humans and other mammals (21, 58). Zika virus has been identified in the salivary glands of field-collected specimens of *Ae. vexans* in Mexico (59). In Italy, *Ae. vexans* is considered one of the principal vectors of setariasis (52). Furthermore, this species has been linked to the spread of the Snowshoe hare virus, Jamestown Canyon virus, Semliki Forest virus (SFV) and Batai virus (60, 61).

Aedes vexans, previously included four subspecies: *Ae. vexans vexans*, *Ae. vexans nipponii* (Theobald, 1907), *Ae. vexans arabiensis* (Patton, 1905) and *Ae. vexans nocturnus* (Theobald, 1903), which were raised to valid species (62). Only *Ae. vexans* has been found in Iran (2).

Aedes (*Dahliana*) *echinus* (Edwards, 1920) [*Dahliana echinus* (Edwards)]

Aedes echinus larvae are found in habitats similar to those of *Ae. geniculatus* and may also be found in root holes of olive trees, where they feed on microorganisms present in these environments (6).

This species has been reported throughout the Mediterranean region, North Africa, Asia and southern Europe (6, 63). In Iran, *Ae. echinus* larvae were first identified in Sari, Mazandaran Province, in 1955 (64). Later, in 2002, larvae of this species were collected in Guilan Province by Azari-Hamidian (33). However, in 2010 and 2022, the species was reported only in its adult stage in Mazandaran Province (24, 65). During an entomological surveillance study of *Aedes* mosquitoes conducted in Mazandaran Province between 2014 and 2020, only two *Ae. echinus* larvae were collected, both in 2015 (45). In addition, the presence of the species was confirmed in both larval and adult stages in Kalaleh County, Golestan Province (66).

Although *Ae. echinus* has been recorded in surveillance studies in northern Iran, available literature provides little evidence regarding its anthropophily or vector competence, and its role in human disease transmission remains unclear.

Aedes (*Dahliana*) *geniculatus* (Olivier, 1791) [*Dahliana geniculata* (Olivier)]

Aedes geniculatus, often referred to as the tree-hole mosquito, is a species that originates from Europe and North Africa. It is phylogenetically related to *Ae. albopictus*. The larvae primarily develop in water-filled tree holes found at various heights in deciduous forests, as well as in mixed forests containing mature trees. The larvae may also be found in man-made receptacles located in peri-urban environments and around human dwellings (67). The eggs of *Ae. geniculatus* are highly resistant to both des-

iccation and freezing temperatures, allowing the species to survive adverse environmental conditions. In temperate regions, the species typically overwinters in the egg stage, while in warmer southern regions, it may overwinter as larvae (6).

Aedes geniculatus is primarily exophilic and exhibits aggressive host-seeking behavior. Females feed on a variety of vertebrate hosts and are active during the daytime and crepuscular periods, when they readily seek blood meals. Adult emergence generally occurs during the summer months, as larval development depends on rainwater accumulating in tree holes during spring and summer. In southeastern Europe, large populations may develop, resulting in considerable biting nuisance to humans in outdoor environments. Nevertheless, this species rarely penetrates densely urbanized areas (4, 6).

Aedes geniculatus is found in the Palaearctic Region and is commonly found across Europe, the Mediterranean region, North Africa and the Middle East (6, 68). In Iran, *Ae. geniculatus* was first reported in Golestan, Guilan and Mazandaran Provinces in the northern part of the country (32, 69, 70). Subsequent records confirmed its presence in Ardebil (71), Guilan (36, 37, 72) and West Azerbaijan (73).

This species is recognized as one of the predominant mosquito species found in the forest ecosystems of northern Iran (65, 74). However, in Guilan Province, adults have only been collected from Rasht and Bandar Anzali (24). In Mazandaran Province, *Ae. geniculatus* has been identified as the most prevalent mosquito species, with a greater frequency of encounters in natural breeding sites, especially tree holes, compared to artificial environments. Larvae were commonly associated with turbid water bodies lacking aquatic vegetation (45). In Golestan Province, northeastern Iran, *Ae. geniculatus* showed a preference for permanent habitats characterized by slow-moving water and muddy substrates. This species was also frequently collected from breeding sites devoid of vegetation (66).

Experimental evidence suggests that *Ae. geniculatus* can transmit the yellow fever virus (YFV) and the eastern equine encephalitis virus (EEEV) (19). It has also been identified as a competent vector for *D. immitis* and *D. repens* (6, 75), as well as CHIKV (76). Prudhomme et al. (76) reported that *Ae. geniculatus* shows a high susceptibility to CHIKV infection and is capable of efficiently transmitting the virus in laboratory settings. Furthermore, the research revealed that the extrinsic incubation period of CHIKV in *Ae. geniculatus* is several days longer than that observed in *Ae. albopictus*. This indicates a slower transmission dynamic, even though *Ae. geniculatus* shows high susceptibility to the virus.

Aedes (*Fredwardsius*) *vittatus* (Bigot, 1861) [*Fredwardsius vittatus* (Bigot)]

The subgenus *Fredwardsius* was established on the basis of its type species, *Ae. vittatus*. This species has long been recognized as not fitting completely within any of the previously described subgenera of *Aedes*, which led to the creation of a separate taxonomic grouping (77).

The primary larval habitats of *Ae. vittatus* are rock pools and rock holes containing water. However, immature stages have also been recorded from tree holes, bamboo stumps, hoof prints, wells and various artificial containers. The females typically oviposit above the water surface. Deep rock holes containing clear water, along with accumulations of mud and decomposing leaf litter at the bottom, are particularly favorable breeding sites for *Ae. vittatus* larvae. The eggs demonstrate a strong resilience to drying out and can remain viable for several years under drought conditions (6, 77, 78).

In France, *Ae. vittatus* is primarily a crepuscular species, although its biting activity may continue throughout much of the night (79). In the Mediterranean region, adults are generally present from late spring to early autumn, with seasonal abundance largely influenced by local rainfall patterns and river water levels. Reports indicate that biting activity occurs both indoors and outdoors at similar intensities. Females may occasionally attack humans in large numbers and readily feed on human hosts. Peak

biting activity occurs during a relatively short crepuscular period, typically between 18:00 and 21:00 hours. Although *Ae. vittatus* is capable of surviving cold winters in northern regions, sufficiently high summer temperatures are required to complete at least one gonotrophic cycle (6, 78).

Aedes vittatus is native to tropical Africa and Asia and is widely distributed across the Mediterranean, Afrotropical, and Oriental regions, with records from Europe, the Americas, the Caribbean, the Middle East and Central and South Asia (6, 77, 80-84). This species was first reported in Hormozgan Province of Iran by Zaim et al. (64) in 1984. More recently, it was recorded in Hormozgan (38), Kerman (85, 86) and Khuzestan (87) Provinces.

Aedes vittatus is considered the primary vector of Setariasis in India (88). In Africa, particularly in gallery forests and savannah ecosystems, it has been recognized as a potential vector for YFV in West Africa (6). Furthermore, studies conducted in Senegal have suggested that *Ae. vittatus* may be capable of transmitting ZIKV, highlighting its potential importance in arbovirus transmission cycles (89, 90). Research indicates that this species is involved in the maintenance and spread of various arboviruses, including yellow fever, dengue, chikungunya and Zika viruses in Africa (81, 91). The detection of WNV in the saliva of *Ae. vittatus* showed its potential as a bridge vector, raising concerns, particularly in areas where virulent strains of WNV are prevalent (92). It is among the known vectors of the Semliki Forest virus (SFV) (61).

Aedes vittatus is likely to spread and establish itself in new areas if introduced. Recent studies indicate that it is adaptable to a variety of habitats and can reproduce in both natural and artificial containers, raising concerns about its potential for wider invasions. This species can thrive in rural, peri-urban and urban environments, making it versatile and not confined to a single niche. Given its high predicted invasive potential, *Ae. vittatus* has a significant chance of colonizing new areas, particularly in warm coastal regions, and may become a priority for vector surveillance in the future (93). The species is a high-potential invasive that has successfully established itself in the Americas. Originally native to Africa, Asia and southern Europe, ecological niche models predict that it may expand further into colder climates and coastal regions of the United States (94). Therefore, *Ae. vittatus* is becoming a significant public health concern that demands urgent attention.

Aedes (*Ochlerotatus*) *asiaticus* Edwards, 1926 [*Ochlerotatus asiaticus* (Edwards)]

Aedes asiaticus was once classified as a subspecies of *Ae. pulcritarsis*. However, integrated morphological and molecular investigations of populations formerly identified as *Ae. pulcritarsis* suggested that this taxon represents a complex of closely related species. Consequently, *Ae. asiaticus* is currently recognized as a distinct species in the Encyclopedia of Life (62) and is now recognized as a distinct species in Iran (2).

Based on current knowledge, this species is found in Afghanistan, Iran and Kazakhstan (62). Wilkerson et al. (4) reported it from Bangladesh, China, India, Nepal, Pakistan and Sri Lanka. Currently, there is limited information on the distribution of *Ae. asiaticus* in Iran, probably in northern and northwestern areas of the country (2).

Aedes (*Ochlerotatus*) *caballus* (Theobald, 1912) [*Ochlerotatus* (*Juppius*) *caballus* (Theobald)]

Aedes caballus, an Afrotropical species (64), inhabits vegetated water bodies that are periodically replenished by rainfall or irrigation. It is generally univoltine, with staggered egg hatching that enhances survival under variable environmental conditions. Adults are rarely found indoors, and females feed on humans and other mammals, often causing painful bites (95).

Studies conducted in Sudan and South Africa indicate that this species predominantly inhabits rural environments, suggesting a strong preference for these types of habitats (96, 97). In the Middle East, *Ae. caballus* has been reported from Iran, Saudi Arabia and Yemen (4).

In Iran, *Ae. caballus* was first recorded in 1935 in Hormozgan Province (98). Following this initial record, a limited number of larvae were reported from Minab and Bashagard Counties in the same province (64, 99). In 1983, larvae of *Ae. caballus* were also reported in Iranshahr, Sistan and Baluchistan Province (64). The extensive and diverse aquatic habitats formed after monsoon rains provide favorable conditions for the proliferation of *Ae. caballus* populations in southeastern Iran (100). This species has also been reported in several other studies from Hormozgan (38, 101) and Sistan and Baluchistan (27, 47, 49) Provinces, further confirming its distribution in southeastern regions of the country.

Aedes caballus is a vector of several arboviruses, including RVFV, Wesselsbron virus (WSLV), Middelburg virus (MIDV), WNV, Cell Fusing Agent virus (an insect-specific virus), and other infectious agents. Its population dynamics are strongly influenced by rainfall, linking its reproductive cycle to the occurrence of Rift Valley fever outbreaks (95, 96, 102–107).

Aedes (*Ochlerotatus*) *caspius* (Pallas, 1771) *sensu lato* [*Ochlerotatus caspius* (Pallas) *sensu lato*]

Aedes caspius s.l., often referred to as the salt marsh mosquito, is a species of floodwater mosquito that is commonly found across the western Palearctic region (108). In temperate climates, this species overwinters in the egg stage and emerges in spring following river flooding (109). Females lay their eggs singly or in small groups on the surface of shallow, stagnant, sun-exposed water bodies with muddy substrates and little or no vegetation. The larvae develop in habitats with a broad range of salinity levels, including coastal beaches, irrigation canals, marshes and rice fields (110). *Aedes caspius* s.l. is known for its aggressive host-seeking behavior and marked exophilic tendencies. It actively bites humans and domestic animals both indoors and outdoors, during both daytime and nighttime hours (111–113). Furthermore, this species is capable of long-distance dispersal, with adults reported to fly up to 15 km from their breeding sites (6, 109).

Aedes caspius s.l. possesses efficient osmoregulatory mechanisms that enable it to tolerate high salinity. Consequently, its populations are primarily influenced by periodically flooded saline habitats rather than by rainfall or other meteorological variables (45, 114, 115).

Aedes caspius s.l. has a broad geographic distribution spanning Europe, Asia, Africa and China (113, 116, 117). In Iran, this species was reported from the Persian Gulf without an exact locality by Edwards (25). Also, it was recorded in northern Iran, Golestan, Mazandaran and Semnan as a new record by Gutsevich (32). The species has been reported from numerous provinces, including Ardebil (26, 71), Bushehr (27), Chaharmahal and Bakhtiari (118, 119), East Azerbaijan (28–30, 50), Fars (31), Golestan (66, 120, 121), Guilan (34, 72, 122) Hormozgan (39, 123, 124), Isfahan (40, 41, 125), Kerman (27), Kermanshah (42), Khuzestan (27, 87, 126-128), Kurdistan (42, 43, 129), Lorestan (70), Mazandaran (45, 46), North Khorasan (130), Qom (131, 132), Razavi Khorasan (70), Semnan (32), Sistan and Baluchistan (27, 47-49), West Azerbaijan (50, 73, 133–136), Yazd (70) and Zanjan (70).

Phylogenetic studies have revealed substantial genetic diversity among Iranian populations of *Ae. caspius* s.l., suggesting a long history of establishment within the country and supporting the hypothesis that this species is native to Iran (137).

Aedes caspius s.l. is considered a competent vector due to its anthropophilic feeding behavior. In Europe, this mosquito species has been implicated in the transmission of various pathogens. Notably, it has the highest infection rate of TAHV, which causes Valtice fever, in Emilia-Romagna, Italy (55, 138–141). Additionally, *Ae. caspius* s.l. has been reported as a potential vector for other pathogens, including *D. immitis* and *D. repens*, RVFV, CHIKV and ZIKV (71, 142–147). Although WNV has been detected in field-collected *Ae. caspius* s.l. pop-

ulations in Iran (148), experimental studies in France demonstrated that this species is unable to transmit the virus (149). This suggests that *Ae. caspius* s.l. may act as a bridge vector or incidental carrier rather than a competent vector. Similarly, studies conducted in Spain found that *Ae. caspius* was not capable of transmitting ZIKV (147). This species is recognized as the principal vector of setariasis, a parasitic disease caused by filarial nematodes of the genus *Setaria* in Italy (52, 150), and avian *Plasmodium* in Spain (151).

Aedes caspius s.l. is a species complex including species A and B. This species previously included three subspecies: *caspius* (Pallas, 1771), *hargreavesi* (Edwards, 1920), and *meirai* (Ribeiro, da Cunha Ramos, Capela and Pires, 1980). *Aedes hargreavesi* is now considered a valid species, and *meirai* is a junior subjective synonym of *Ae. caspius* (62). *Aedes hargreavesi* has not been recorded in Iran (2).

Aedes caspius s.l. raises concerns because its distribution is already broad and its ecological tolerance may allow further range shifts under environmental change (147).

Aedes (*Ochlerotatus*) *detritus* (Haliday 1833) [*Ochlerotatus detritus* (Haliday)]

Aedes detritus, often referred to as the salt-marsh mosquito, is a multivoltine, strongly halophilic mosquito that typically overwinters in the egg stage. Its larvae develop mainly in highly saline coastal and brackish habitats, where the species may occur as the dominant or sole mosquito, although reduced salinity can facilitate coexistence with other species such as *Ae. caspius* (6, 152).

Adult female mosquitoes are known to be aggressive and persistent biters that frequently attack humans in large numbers. They are active during daylight hours, especially at dusk (6). Rioux (79) described *Ae. detritus* as a predominantly exophilic species that only occasionally enters buildings. In contrast, Cranston et al. (153) classified it as an endophagous species, although adults typically do not rest indoors. In the United Kingdom, *Ae. detritus* was responsible for the majority of mosquito bite nuisance complaints (154).

Aedes detritus is a Palearctic species widely distributed across Europe, northern Africa and southwestern Asia, particularly in coastal regions associated with the North Sea, Baltic Sea, Atlantic Ocean and Mediterranean basin (6).

In Iran, *Ae. detritus* was first identified in Hormozgan Province by Zaim et al. (64) in 1984. It has since been reported in Chabahar and Konarak Counties in Sistan and Baluchistan Province (48), as well as in Bushehr (27) and Kerman (85) Provinces.

While information regarding the vector competence of *Ae. detritus* remains limited, available evidence suggests that this species could potentially act as a vector for the Japanese encephalitis virus (JEV) (155) and TAHV (61). A study performed in the UK demonstrated that *Ae. detritus* is capable of transmitting WNV under laboratory conditions (156). This mosquito may also transmit the agent of canine dirofilariasis (157). *Aedes detritus* is considered to have invasive or expansion potential because it is ecologically well adapted to saline and coastal habitats. This potential is best interpreted as a capacity for continued range maintenance and local expansion, rather than evidence of rapid worldwide invasion (156).

The *Ae. detritus* complex comprises two species, *Ae. detritus* and *Ae. coluzzii*. *Aedes coluzzii* has not been recorded in Iran (158).

Aedes (*Ochlerotatus*) *flavescens* (Müller, 1764) [*Ochlerotatus flavescens* (Müller)]

Aedes flavescens is a univoltine species that overwinters in the egg stage and hatches in spring under favorable conditions. Its larvae tolerate a broad range of salinities and inhabit partially sunlit coastal salt marshes and temporary freshwater floodplain pools. Adult females are primarily exophagous, with peak biting activity at dawn and dusk, although their specific host preferences remain poorly understood (6).

Aedes flavescens is a Holarctic species distributed across both Eurasia and North America. It is commonly seen throughout Europe, though it is rare or absent in some Mediterranean countries. Its broad geographic range reflects its ability to exploit a variety of wetland habitats across temperate climatic regions (6).

In Iran, *Ae. flavescens* has been documented in the provinces of Ardebil (26), Kerman (85), Mazandaran (45), Sistan and Baluchistan (27) and West Azerbaijan (133). This species was found for the first time in West Azerbaijan Province in 1984 by Zaim et al. (64). Available records suggest that *Ae. flavescens* may be relatively widespread in the northern regions of the country. However, ecological and biological information on this species in Iran remains limited, highlighting the need for further studies on its distribution, habitat preferences, seasonal dynamics, and potential role in pathogen transmission (45).

The TAHV has been frequently isolated from *Ae. flavescens*, indicating its potential role in the maintenance and transmission of the virus (6).

***Aedes* (*Ochlerotatus*) *leucomelas* (Meigen 1804) [*Ochlerotatus leucomelas* (Meigen)]**

Aedes leucomelas is a monocyclic species. The larvae typically emerge in early spring following snowmelt. Breeding habitats are commonly found along forest margins, in flooded pastures, and within reed-dominated wetlands. Larvae have also been recorded in slightly saline water bodies, similar to those occupied by *Ae. detritus*, such as flooded coastal meadows. These observations indicate a degree of tolerance to elevated salinity in the immature stages (6).

This mosquito species is primarily found across northern, central and eastern Europe. Its occurrence in southern Europe appears to be limited, with records predominantly from Spain (6). In Iran, *Ae. leucomelas* was first reported by Zaim et al. (64) in Hormozgan Province in 1984. Paksa et al. (85) reported this species from Kerman Province. However, information regarding its current distribution, ecology and potential public health significance in the country remains limited and warrants further investigation.

***Aedes* (*Ochlerotatus*) *pulcritarsis* (Rondani, 1872) [*Ochlerotatus pulcritarsis* (Rondani)]**

Aedes pulcritarsis previously included two subspecies, *asiaticus* and *pulcritarsis*, which are now considered to be separate valid species (62). *Aedes pulcritarsis* larvae develop in tree holes (phytotelmata) found in mature deciduous and shaded forests, particularly in mountainous regions with high rainfall. They are most commonly associated with oak, plane and eucalyptus trees (68). The water temperature in their natural breeding sites generally does not exceed 21°C, and the larval development process can last as long as two months. This species overwinters in the egg stage and typically completes one to two generations each year (6).

Adult females are anthropophilic and bite outdoors, primarily during daylight hours. Both male and female mosquitoes have been found in stables and rural houses lacking nearby trees, suggesting that the species may be facultatively zoophilic and capable of breeding in artificial containers or possessing significant dispersal ability. However, due to its rarity and preference for forest habitats, *Ae. pulcritarsis* rarely comes into contact with humans (6).

Aedes pulcritarsis is a Western Palaearctic species primarily distributed throughout the Mediterranean region, with a range extending northward to the Czech Republic. This species is also found in Central and Southeast Asia and has been reported in more than 30 countries, including Austria (159), France, Georgia, Greece, Italy, Spain, Tunisia, Turkey (108), Germany (160), Iran (161) and Palestine (68).

This species was reported in Iran without an exact locality for the first time by Edwards (25). Gutsevish (32) reported it as a new record from Golestan, Mazandaran and Semnan Provinces. Zaim (125) reported finding adult specimens of *Ae. pulcritarsis* in Kashan County,

Isfahan Province, central Iran, which has a dry climate, while most reports of this mosquito are from northern provinces with temperate climates. However, subsequent surveys conducted in Kashan County in 2021 failed to detect the species (162, 163). Additionally, Zaim et al. (64), Monchadskii (164) and Minar (165) have documented the presence of this species in Iran. Azari Hamidian et al. (122) found this species for the first time in Guilan Province. It has recently been reported again from Guilan (24) and Mazandaran (65).

At present, there is no evidence that *Ae. pulcritarsis* plays a role in transmitting human pathogens. Its infrequent presence in densely populated regions and, along with its limited breeding habitats, likely decrease its potential impact on public health (159).

Aedes (*Stegomyia*) *aegypti* (Linnaeus 1762) [*Stegomyia aegypti* (Linnaeus)]

Aedes aegypti, widely known as the yellow fever mosquito, originates from Africa (166). This species was previously classified into two subspecies: *Ae. aegypti aegypti* and *Ae. aegypti formosus* (Walker) (3, 63). *Aedes formosus* is now considered to be a valid species in Sub-Saharan Africa and is listed in the Encyclopedia of Life (62).

Aedes aegypti is believed to have evolved from the zoophilic forest-dwelling *Ae. formosus* in sub-Saharan Africa. Evolutionary adaptation led to the emergence of *Ae. aegypti*, a domesticated form that preferentially feeds on humans, breeds in artificial containers, and frequently takes multiple blood meals per gonotrophic cycle, thereby increasing its vectorial capacity (167–169).

The establishment of permanent human settlements in Africa promoted the domestication of *Ae. aegypti*, as water-storage containers created suitable breeding habitats during dry seasons and humans became the primary blood source. This human-adapted form subsequently spread across six continents and is now widespread in tropical and subtropical urban regions worldwide (169, 170).

Several biological and ecological characteristics contribute to the success of *Ae. aegypti*. These include its behavioral plasticity, rapid developmental cycle, desiccation-resistant eggs, resistance to major classes of commercially available insecticides, a preference for urban habitats, and close association with human populations (171, 172).

Aedes aegypti is widely distributed across tropical and subtropical regions worldwide, including Africa, Southeast Asia, the Middle East, northern Australia and parts of the Americas. Although its presence in Europe remains limited, its range is expanding. The species has been reported in 167 countries, including several neighboring countries of Iran (4, 173–177).

In Iran, *Ae. aegypti* was initially identified in Khorramshahr, Khuzestan Province, in 1920, and later in Bushehr, Bushehr Province, in the early 1950s (69, 178). After these initial reports, no further records of the species were documented until 2019. In March 2019, *Ae. aegypti* was observed in Bandar Lengeh and subsequently in Bandar Abbas, both located in Hormozgan Province (38, 179). The species is now established throughout Hormozgan Province (179) and has also been reported in Sistan and Baluchistan (180), Bushehr, Fars and Kerman Provinces (179). As entomological surveys continue and more provinces in Iran are explored, it is anticipated that the known distribution of the species will increase (181). Unfortunately, resistance to several commonly used insecticides has already been documented in Iranian populations of *Ae. aegypti* (182).

Aedes aegypti is the primary vector for several medically important arboviruses, including DENV, ZIKV, YFV, CHIKV and WNV (although *Culex* species are the primary vectors of WNV). These pathogens pose major public health challenges globally, causing millions of infections each year (169, 183). Additionally, *Plasmodium gallinaceum* and *P. lophurae* have been isolated from this species

(4). *Aedes aegypti* is also a known vector of dirofilariasis (184). The mosquito's remarkable ability to thrive in and adapt to urban environments has greatly contributed to its success as a disease vector (185). The global spread of *Ae. aegypti* has been further facilitated by human migration, international trade, transportation networks, and rapid urbanization (169, 183).

***Aedes* (*Stegomyia*) *albopictus* (Skuse 1895) [*Stegomyia albopicta* (Skuse)]**

Aedes albopictus, the Asian tiger mosquito, is native to the tropical and subtropical forests of Southeast Asia but has become one of the world's most invasive mosquito species. Over the past five decades, it has spread to every continent except Antarctica, largely through human activities, such as the transportation of eggs in used tires, the trade of lucky bamboo plants, and other commercial products (186–188).

Aedes albopictus exhibits remarkable ecological plasticity, enabling it to adapt to a wide range of environments, including urban settings and colder climates. This species can utilize numerous types of small water-holding containers as breeding sites, such as discarded tires, refuse, flowerpot saucers, and other artificial containers (189).

Aedes albopictus is an opportunistic feeder with a broad variety of hosts (190). Its bloodmeal sources include humans, domesticated and wild mammals, reptiles, birds, and amphibians (191). This mosquito is known for its aggressive biting behavior, making it a considerable nuisance (187).

Aedes albopictus is widely distributed across tropical and temperate regions worldwide, with established populations in Asia, the Middle East, Europe, Africa, Australia and the Americas. The species has been reported in 126 countries, and its geographic range is expected to continue expanding (4, 6, 192–194).

Doosti et al. (27) documented the presence of *Ae. albopictus* in Sistan and Baluchistan Province, Iran, for the first time in areas along the border with Pakistan. Despite extensive surveillance efforts in subsequent years, no additional specimens of the species were found in the province (47, 177). After several years without detection, *Ae. albopictus* was reported again in Iran from Guilan Province in 2023 (195). Currently, the species has been recorded in Ardebil (196), East Azerbaijan (28), Guilan (195), Mazandaran (197), Qazvin (179) and Zanjan (198) Provinces.

Aedes albopictus is of medical and veterinary importance as a vector of at a minimum 22 arboviruses, the most important of which are CHIKV, DENV, JEV, WNV, YFV, ZIKV, EEEV and La Crosse virus (186). Moreover, this species has been found to harbor *Dirofilaria immitis*, *Plasmodium gallinaceum*, *P. fallax* and *P. lophurae* (4).

Aedes albopictus is generally considered a secondary vector for CHIKV and DENV compared to *Ae. aegypti* and tends to feed in outdoor settings. The opportunistic feeding behavior of *Ae. albopictus* decreases its efficiency in acquiring and transmitting the dengue virus. Consequently, dengue outbreaks in areas solely inhabited by *Ae. albopictus* are generally less intense than those in regions where *Ae. aegypti* is also found (199). *Aedes albopictus* is highly adaptable and can survive sub-zero temperatures, allowing it to occupy a wider geographical area than *Ae. aegypti* in temperate climates (200, 201).

***Aedes* (*Stegomyia*) *unilineatus* (Theobald, 1906) [*Stegomyia unilineata* (Theobald)]**

Information on the ecology of *Ae. unilineatus* remains limited. Larvae have most frequently been collected from tree holes and rock pools (202, 203). In Pakistan, they have been collected from two types of breeding sites: bamboo stumps and discarded artificial containers (204). Godsey et al. (205) suggested that the primary larval habitats of *Ae. unilineatus* in Saudi Arabia include rock holes, small ponds and artificial containers located around residential areas. The authors further proposed that the species may have been introduced into Saudi Arabia through the move-

ment of people and goods between East Africa and the Arabian Peninsula. Mattingly (206) described *Ae. unilineatus* as a savannah-associated species with a high tolerance to drought and noted that it has not been recorded in African regions receiving more than 140 cm of annual rainfall.

Aedes unilineatus has been documented in various countries across Africa and Asia (205, 207, 208). In Iran, this species was first recorded in Sistan and Baluchistan Province, with its identification later confirmed through COI gene sequence analysis (48). The species was also found in Kerman Province (Dehghan and Azari-Hamidian, personal communication).

Aedes unilineatus is one of the mosquito species that have tested positive for the Zika virus (209). In 2014, Diallo et al. (89) documented the natural infection of *Ae. unilineatus* with the Zika virus in southeastern Senegal. In addition, the species has been identified as a probable vector of dengue virus in Karachi, Pakistan (210). However, no records of arbovirus isolation from *Ae. unilineatus* have been reported from Saudi Arabia (205). Despite these findings, the epidemiological significance of *Ae. unilineatus* remains poorly understood. More research is needed to clarify its role in the maintenance and transmission of arboviruses in endemic regions.

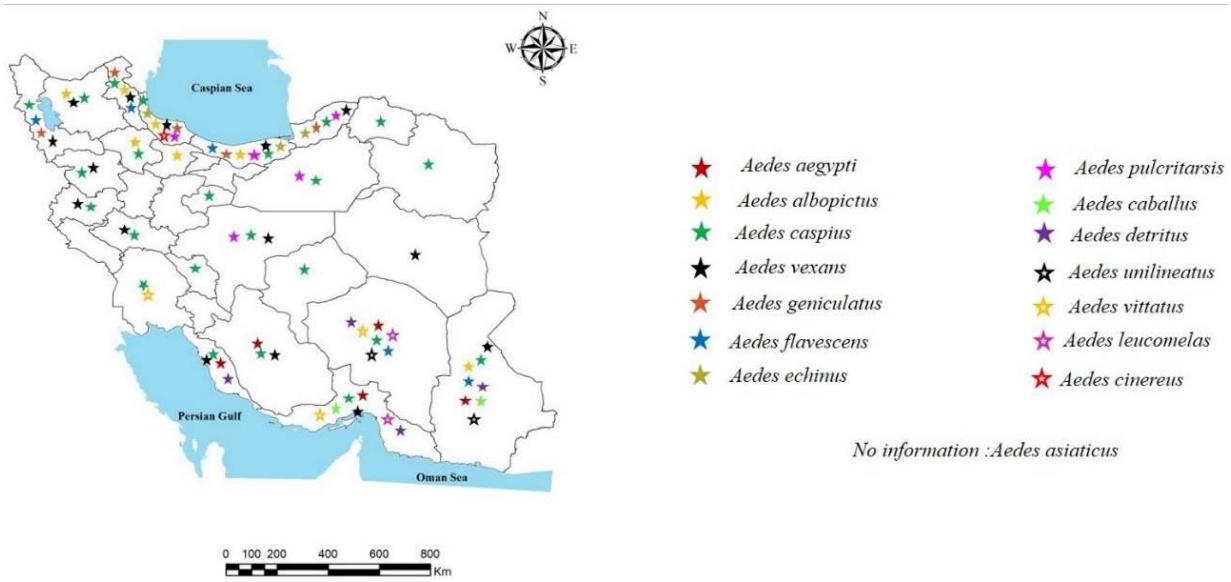


Fig. 1. Provincial distribution map of reported *Aedes* species in Iran

Discussion

The changing distribution of *Aedes* species in Iran, particularly the establishment of invasive vectors such as *Ae. aegypti* and *Ae. albopictus*, highlights the urgent need for predictive and applied research. While existing studies provide a foundational baseline for species occurrence, significant knowledge gaps remain, hindering the development of effective, evidence-based vector management strategies in the region.

Specifically, the lack of sufficient ecological and molecular data in Iran hinders the accurate prediction of shifts in high-risk hotspots driven by climate change and urbanization. Furthermore, the absence of comprehensive information on the status of insecticide resistance across various provinces poses a significant risk; relying on current chemical control measures without these insights may increase selection pressure and reduce insecticide efficacy. Ad-

ditionally, vector competence among *Aedes* mosquitoes in Iran remains insufficiently characterized. There is a critical lack of detailed studies examining how local strains interact with circulating arboviruses within the specific ecological context of Iran.

Finally, although the One Health approach is conceptually recognized, its practical integration into Iranian public health policy remains fragmented. There is an urgent need for a unified framework that links entomological surveillance with veterinary, environmental and epidemiological data to transition from reactive measures to a proactive, integrated control system.

This review, while comprehensive, does have certain limitations that need to be acknowledged. A major limitation is the incomplete geographical coverage across all provinces in the country. Due to limited access to data and the absence of regular entomological sampling or surveillance studies in specific regions, we were unable to provide a detailed analysis of *Aedes* species distribution in those areas. Additionally, variations in the sampling protocols and methodologies used in different national studies may result in perceived discrepancies regarding the reported distribution of these species. Future research should focus on systematic surveillance in the underrepresented provinces. Nevertheless, the findings from the regions studied offer valuable insights into the current status and expansion trends of these mosquitoes in Iran.

Conclusion

This review highlights the dynamic nature of the *Aedes* fauna in Iran, encompassing 15 documented species across diverse ecological zones. While the presence of key vectors such as *Ae. aegypti* and *Ae. albopictus* is well established, rapid changes in species distribution and the potential emergence of additional species necessitate a shift in research priorities. Moving forward, Iranian entomological research must focus on addressing critical knowledge gaps, specifically the characterization of insecticide resistance mechanisms, ecological niche modeling, and the investigation of vector competence and microbial interactions. Strengthening these scientific foundations is essential for developing evidence-based, integrated and sustainable strategies to mitigate the risk of *Aedes*-borne disease outbreaks in the country.

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Ethical considerations

None.

Conflict of interest statement

The authors declare that there is no conflict of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly and Wordvice AI in order to improve readability and language of the work. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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