Vectors Without Borders: Imminent Arrival, Establishment, and Public Health Implications of The Asian Bush (*Aedes Japonicus*) and Asian Tiger (*Aedes Albopictus*) Mosquitoes in Turkey

Sınır Tanımayan Vektor Sivrisinekler: Kaçınılmaz Ülkeye Giriş ve Yayılış, Yayılışı Takiben Asya Cali ve Asya Sivrisineklerinin İnsan Sağlığı Üzerinde Oluşturabileceği Olumsuz Etkiler

Research Article

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ABSTRACT

Aedes albopictus and *Aedes japonicus* are invasive mosquito species with expanding distributions. Both species are indigenous to the tropical and sub-tropical regions of Southeast Asia; however, they have rapidly established populations in several countries outside their native range over the last few decades. The European continent has not been excluded from these invasions. *Aedes albopictus* was first reported from Albania in 1979, subsequently from Italy, France, Greece, Switzerland, Belgium, Spain, Netherlands and Germany. *Aedes japonicus* was first reported from France in 2000, in Belgium during 2002, and from Germany in 2007. The potential risk for further invasion and/or expansion of either species may be projected based on their biology. Temperate countries in Europe such as Turkey are vulnerable to potential introductions of these invasive species. Existence of a national surveillance program would be a valuable proactive measure for the detection and rapid intervention efforts to prevent establishment of these nuisance mosquito species and the diseases they may transmit. We provide a brief historical background, biology, ecology, larval identification, public health implications, suitable climate areas, and routes of introduction for *Ae. albopictus* and *Ae. japonicus* in Turkey.

Key Words
Invasive species, Exotic, Arboviruses, Public health, Introduction routes

ÖZET

Aedes albopictus ve *Aedes japonicus* sınırlarını her gecen gün genişleten sivrisinek türleridir. Her iki tür de tropik ve tropik iklime yakın olan Güneydoğu Asya ülkelerinde yerli olmakla birlikte, son 30 yılda diğer ülkelerde de hızlı bir yayılış göstermektedirler. Avrupa ülkeleri de bu hızlı yayılıştan etkilenmişlerdir. *Aedes albopictus* ilk kez 1979'da Arnavutluk'da, daha sonra sırasıyla İtalya, Fransa, Yunanistan, İsviçre, Belçika, İspanya, Hollanda ve Almanya'da kaydedilmiştir. *Aedes japonicus* ilk kez Fransa'da 2000 yılında, Belçika'da 2002 yılında ve Almanya'da 2007 yılında tespit edilmiştir. Bahsedilen her iki türün de biyolojisine bakıldığında, bu türlerin Avrupa'da başka ülkelere girişi ve yayılma riski söz konusudur. Avrupada Türkiye gibi ılıman ülkeler bu türlerin giriş ve yayılışı için risk altındadır. Bu ülkelerin uygun teknikleri kullanarak sözü geçen türleri izlemeleri, hem sebep olabilecekleri hastalıkları hem de verecekleri rahatsızlığı önleme açısından, cok önemlidir. Bu makalede *Ae. albopictus* ve *Ae. japonicus* türlerinin tarihçeleri, biyolojileri, ekolojileri, larvalarının teşhisi, halk sağlığı açısından önemleri, yayılımları için uygun alanlar ve giriş yolları ana hatlarıyla tartışılmıştır.

Anahtar Kelimeler
İstilacı türler, Dış kökenli türler, Arbovirüsler, Halk sağlığı, Ülkeye giriş yolları

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INTRODUCTION

The field of invasion biology focuses on patterns and processes related to introduction, establishment, spread, and impacts on non-native species [1]. Juliano and Lounibus [2] describe an invasive species as an introduced organism which has increased its abundance and expanded its geographical range, thus creating the potential for impact on native species and ecosystems, or on human activities (agriculture, conservation, or health). Mosquitoes are amongst some of the most invasive animals known to man, and *Aedes* (*Stegomyia*) *albopictus* (Skuse) and *Aedes* (*Finlaya*) *japonicus* (Theobald) (Diptera: Culicidae) are two of the most invasive mosquito species in the world [3].

Mosquitoes may invade new geographical areas via active flight dispersal [4] or through human-facilitated activities [4,5]. In fact, human movement has been responsible for the arrival and spread of most invasive mosquito species [1], primarily because of the advances in transportation technology and international trade. The impacts of globalization have augmented the capacity of pests and vectors to be introduced into new areas and to establish stable populations, while triggering increased threats to human and animal health.

In particular, the international trade in used auto-mobile tires has been a major contributing factor for the dispersal of exotic container-inhabiting *Aedes* species of medical importance [5]. Multivoltine *Aedes* species utilize container habitats by ovipositing dessication-resistant eggs that survive drought for extended periods of time. Natural containers utilized by these species include bamboo nodes, plant axils, rock pools, and tree holes; however, discarded tires and a variety of other artificial containers provide suitable habitats which mimic natural oviposition sites. Desiccation-resistant eggs of container *Aedes* have facilitated their invasion into new areas, and with escalating transportation technology and international trade, this trend is unlikely to cease in the foreseeable future.

Moreover, the ubiquity of used tires and other artificial containers in peridomestic habitats pro-hibit effective control of these mosquito species. Since container-inhabiting mosquitoes of the genus *Aedes* are important vectors of arboviruses such as chikungunya (CHIK), dengue (DEN), West Nile (WN), and yellow fever (YF), the public health threat for the introduction of an exotic species into a new area is evident [6]. Proactive surveillance and control measures are needed to identify significant vectors before local establishment and onset of epidemic disease. In many cases, vector suppression is the only means to successfully combat exotic diseases, thus accurate identification of vectors is crucial for initiation of aggressive abatement measures. However, most often, an integrated surveillance and control program may not be established in a region or many vector control personnel are not properly trained to identify and respond efficiently to an introduced species in a new geographic area, particularly in the larval stage when targeted abatement efforts would be most effective.

Vector-borne diseases are debilitating maladies and are considered emerging pathogens because of their geographic range expansions and increasing impact on human health [7]. The 2007 occurrence of the first European outbreak of CHIK virus in Italy [8,9] is a prominent example of the potential public health threat that may arise from a vector-borne disease that can be easily established in a new ecosystem where the appropriate vector is present and conditions are suitable. *Aedes albopictus*, which invaded Italy in the early 1990's and has now spread to most Italian regions, was incriminated as the principal vector of CHIK virus during the 2007 outbreak [10]. This incident highlights the capacity of an invasive vector to impact human health and exposes the continued vulnerability of existing infrastructures, such as those in Turkey, to arboviral pathogens like CHIK virus.

Although there is limited information on arboviral diseases in Turkey, it is apparent that human arboviruses of public health importance have already been circulating in the area for some time [10-12]. Additionally, the climatology of Turkey is suitable for invasion and establishment of such exotic mosquitoes as *Ae. albopictus* and

Ae. japonicus [13]. Both species may tolerate a wide range of environmental conditions, particularly in temperate regions, and although neither species has been detected in Turkey yet (B. Alten, personal communication), the climatic suitability of the country would dictate that it is only a matter of time before the species are introduced and established. The existence of a wide array of entry routes and port cities, coupled with large numbers of used tire imports from foreign areas where the two species are already established, only complicates matters further. Additionally, the lack of a proactive entomological surveillance system on a national scale, limits the true status of important invasive vectors. The arrival, establishment, spread, and public/veterinary health implications of invasive species are imminent.

This paper provides information on the biology and ecology of *Ae. albopictus* and *Ae. japonicus*, with detailed larval photographs to aid in quick identification. We also discuss importation of used tires, major ports of trade, environmental data, and winter isotherms; all determinants for suitable habitat distribution of these invasive species in Turkey. We conclude by imploring for the development and implementation of a national surveillance program to detect and identify invasive species and emerging pathogens.

Aedes (Stegomyia) albopictus

Aedes albopictus, the Asian tiger mosquito, is a model example of an invasive species. Although originating from sub-tropical southeastern Asia, it has since established populations in several regions over the last few decades including Africa, Asia, the Caribbean, Europe, the Middle East, and North and South America [14]. The worldwide expansion of *Ae. albopictus* was first detected in Albania during 1979 [15], and it was then detected in the United States sometime before 1980 [16]. *Aedes albopictus* has since been reported from Israel in the Middle East; Cameroon, Equatorial Guinea, and Nigeria in Africa; and is now widespread in the United States, Central America, and South America [14]. Established European populations of *Ae. albopictus* have now been identified from Albania, Bosnia and Herzegovina, Croatia, France, Greece, Monaco, Montenegro, Italy, San Marino, Slovenia, Spain, southern Switzerland, and Vatican City [13]. Additional European countries such as Belgium, Germany, and the Netherlands have detected the presence of *Ae. albopictus* on separate occasions, but the species has not become established in these areas [13]. The northern range of *Ae. albopictus* is restricted by its inability to survive extreme cold [17], but the species has adapted well to temperate areas and is slowly undergoing range expansion near its northernmost limits [13, 18]. In Italy, *Ae. albopictus* has become the most serious pest and public health mosquito species through most of its range [19, 8], and it continues to pose a threat to other European countries [20].

A selective advantage which facilitates geographic range expansion within container-inhabiting mosquitoes of the genus *Aedes*, is the ability of these species to oviposit desiccation resistant eggs that survive drought for extended periods of time [1]. Dormant eggs within artificial containers, such as tires, assist invasion into new areas, primarily through transport during international trade [21]. Increased global travel and trade in used tires are major contributing factors for the dispersal of exotic species such as *Ae. albopictus*. Eggs are often glued by female mosquitoes to the inside of a container, and once that container is transported to a new area and exposed to rainfall, the eggs are flooded and new hatching will occur. Low oxygen levels within the container may indicate high microbial activity and high nutrient content, thus stimulating increased hatching, followed by larval growth and development [22].

High larval densities may result in higher mortality rates, longer larval development periods, and smaller adult sizes [23]; however, larvae of *Ae. albopictus* can survive long periods of starvation and are more tolerant to overcrowding [22]. *Aedes albopictus* larvae are generally superior competitors and in the southeastern United States, they may have caused local extinctions of *Aedes aegypti* (L.) [2, 24]. Additionally, although *Ae. albopictus* are superior competitors to many other mosquito species, under laboratory conditions, they co-exist in natural habitats where larval predators such as *Corethrella appendiculata* are present [25]. Anti-predatory behavioral responses is argued to be the mechanism behind this co-existence [26].

Larvae of *Ae. albopictus* are predominantly peridomestic and thrive in artificial containers, but may also be found in rural and sylvan areas inhabiting natural containers such as tree holes. *Aedes albopictus* has undergone evolution as a tropical forest mosquito, but it has developed the capacity to exploit artificial environments in urban temperate areas [14]. This species is an opportunistic container-utilizing mosquito and it has greatly taken advantage of the numerous artificial containers readily discarded in metropolitan centers. Although the mosquito is most often associated with discarded tires and in shipments of ornamental plants (1), it has the ability to adapt to an exceptionally wide range of containers. The larval habitats of some populations discovered during larval surveys include animal pans, earthenware containers, flower pots, drums, old car/boats, plastic bottles, rubber tires, tin cans etc. [22, 27]. This long list of artificial containers indicates that *Ae. albopictus* larvae are opportunistic and have the potential of utilizing any kind of available container in peridomestic environments.

Larvae of *Ae. albopictus* may be readily distinguished from other common container-inhabiting *Aedes* by a single neat row of comb scales on abdominal segment VIII, a straight and long median spine on a representative single comb scale, and the presence of a double preantennal setae on the head (Figure 1).

Adult females of *Ae. albopictus* are opportunis-tic feeders and in urban areas are often found in shade near gardens and landscaping. The longevity of the adult mosquito is of great concern because it is directly related with the possibility of disease transmission. The majority of studies determining life expectancy of adult mosquitoes have been conducted under laboratory settings and misleadingly yield longer life span averages than those studies conducted in the wild [28]. North American mark-release-recapture studies in southern United States showed an average of 4 days life expectancy for *Ae. albopictus* females [22], though later studies detected a longer life expectancy of 8 days [29]. Studies conducted in Hawaii concluded average female life spans of 10 days with several females persisting as long as 21 days [30]. Adult survival is dependent on temperature, relative humidity, and feeding [22]. Hylton's [31] field studies found that *Ae. albopictus* are able to survive varying temperatures and humidity, withstanding temperatures as low as 15.5°C while at higher temperatures (32.2°C) survivability decreased [31]. These characteristics lend some insight into the species broad distribution throughout varying climatic zones. Laboratory studies found feeding to be a determining factor of adult longevity as well; female *Ae. albopictus* mosquitoes, kept at optimal conditions and bloodfed, lived from 38-112 days, however those kept at similar conditions, but fed only water, lived no longer than 5-7 days [32]. *Aedes albopictus* adults do not travel long distances nor have they been observed to fly during strong winds [33, 34]. They remain close to the ground and rest in shaded vegetation until host-seeking or ovipositing [35].

Adult female *Ae. albopictus* are primarily diurnal feeders, preferring to attack large mammals including humans and livestock, but may also feed on birds [36]. The public health significance of *Ae. albopictus* has been well documented and the species is considered not only a vector of several arboviruses, but also a significant nuisance where it is abundant. The mosquito has been documented as an efficient laboratory vector of more than thirty arboviruses, including seven alphaviruses (such as eastern equine encephalitis and Ross River), eight bunyaviruses (such as LaCrosse and Rift Valley fever), and four flaviviruses (Japanese encephalitis, DEN, WN, and YF) [6, 22]. Field populations of *Ae. albopictus* have been found naturally infected with CHIK, DEN, Japanese encephalitis, Potosi, Keyston, Tensaw, Cache Valley, eastern equine encephalitis, WN, and YF viruses [6, 37]. *Aedes albopictus* is implicated as a potential bridge vector in the transmission of WN virus [18], and as the principal vector of DEN virus (all four serotypes), dog heartworm, and CHIK virus [6, 38]. Ultimately, increased human travel and dispersal of mosquito vectors will allow a viremic patient to meet a competent vector in a

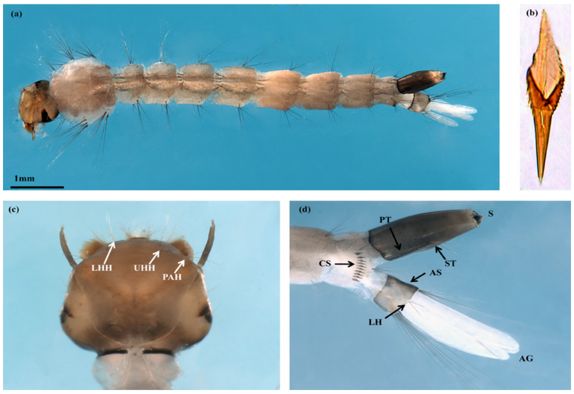

Figure 1. Representative larval specimen of *Ae. albopictus*. (a) Dorsal view of entire fourth instar larva. (b) Dorsal view of head. (c) Lateral view of terminal segment. (d) Close up of representative comb scale. AG, anal gills; AS, anal saddle; C, comb; LH, lateral hair; LHH, lower head hair; PT, pecten teeth; PAH, preantennal hair; S, siphon; ST, siphonal tuft; UHH, upper head hair.

new environment and exotic diseases will undergo establishment, amplification, and dispersal.

Adult *Ae. albopictus* are small to medium in size relative to most mosquito species, with a body length of about 5 mm. They are known as tiger mosquitoes because of their black and white bodies, characteristic striped legs, and a distinctive single white band running dorsally down the length of the head and thorax, allowing for quick and accurate species identification (Figure 2).

Aedes (Finlaya) japonicus

Aedes japonicus, the Asian bush mosquito, is also considered an invasive species. This species originated from Japan, Korea, Taiwan, and eastern China but has also been detected in Russia [39]. Outside its original endemic area, *Ae. japonicus* has been intercepted at a port in New Zealand over the past 75 years and in used tires imported from Japan during 2004 [40], but the first detected establishment of the species outside its endemic range was reported from the northeastern United States in 1998 [41]. Since then, the species has spread rapidly in the United States and is now endemic in 31 states in that country [42, 43]. *Aedes japonicus* is also now widely established in southern Canada near Ontario and Quebec [43, 44]. In Europe, *Ae. japonicus* larvae have been collected in France during 2000, but the species was quickly era-

Figure 2. Adult female *Ae. albopictus* blood feeding.

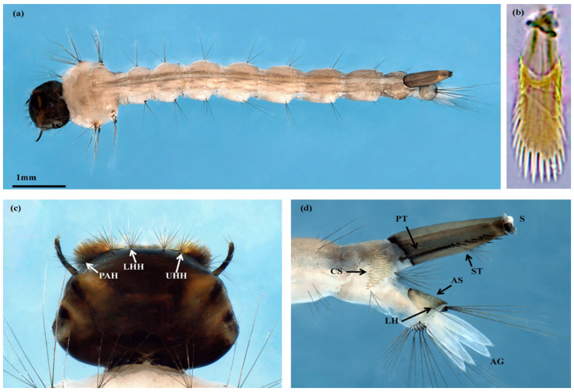

Figure 3. Representative larval specimen of *Ae. japonicus*. (a) Dorsal view of entire fourth instar larva. (b) Dorsal view of head. (c) Lateral view of terminal segment. (d) Close up of representative comb scale. AG, anal gills; AS, anal saddle; C, comb; LH, lateral hair; LHH, lower head hair; PT, pecten teeth; PAH, preantennal hair; S, siphon; ST, siphonal tuft; UHH, upper head hair.

Figure 4. Adult female *Ae. japonicus* blood feeding.

dicated from this location [45]. Since then, established European populations of *Ae. japonicus* have only been documented definitively from Belgium, Germany, and Switzerland [46]. Much like *Ae. albopictus*, introduction via international trade in used automobile tires has been suspected as the primary cause for the initial introduction and dispersal of *Ae. japonicus*. However, temperate strains of *Ae. japonicus* are more tolerant of cold temperatures than *Ae. albopictus*, with eggs and larvae successfully overwintering in northern geographic ranges [37]. In northeastern United States, eggs of this species also hatch earlier than other container-inhabiting mosquitoes, and larvae persist much longer during the fall season, despite near freezing water temperatures [47]. In a survey of rock pools conducted in Connecticut, Andreadis and Wolfe [48] reported *Ae. japonicus* as the dominant mosquito collected from these habitats, except from pools where water temperatures exceeded 30ºC. They have theorized that a temperature barrier may exclude *Ae. japonicus* from expansion into southern states where high summer temperatures are common [48]. Nevertheless, despite limiting environmental barriers, *Ae. japonicus* appears as a dominant invader and may also be competitively displacing native species in certain habitats [48-50].

In the United States, larvae of *Ae. japonicus* are readily detected in domestic and sylvan habitats within a wide variety of small-volume containers of relatively clean and clear water [41, 47, 2]. They are most often recovered from artificial containers, including, buckets, gutter extensions, plant pot receptacles, tires etc., but are also readily collected from natural containers such as treeholes and rockpools [48, 49, 51]. Under laboratory conditions, when kept at a water temperature of 28ºC, larvae spend 2.2 ± 0.5 days in the first instar, 1.6 ± 0.8 days in the second instar, 2.2 ± 1.2 days in the third instar, and 5.6 ± 2.6 days in the fourth instar [47].

Larvae of *Ae. japonicus* may be readily distinguished from associated container-inhabiting *Aedes* species by the arrangement of the head hairs in a straight line near the anterior margin of head and a highly spiculated anal saddle (Figure 3).

Adult populations of *Ae. japonicus* appear to be primarily mammalophilic, with a substantial proportion of blood feedings from field-collected specimens in the northeastern United States deriving from humans [52-54]. Blood meal analysis of field-collected mosquitoes in New Jersey indicated that *Ae. japonicus* acquire blood meals exclusively from mammalian hosts, including white-tailed deer, human, fallow deer, horse, and Virginia opossum [54]. Researchers have not identified any avian, amphibian, reptilian, or mixed blood meals [52-54]; however, laboratory observations have shown *Ae. japonicus* to feed on birds in addition to mammalian species [55, 47]. Furthermore, an established colony of *Ae. japonicus* in the United States has been exclusively maintained by feeding on bobwhite quail, *Colinus virginianus* [56]. Lack of avian-derived blood meals from field-collected mosquitoes may be due to small sizes of field collections or experimental bias in types and locations of traps used to collect engorged mosquitoes.

Adult *Ae. japonicus* rest in wooded areas and may bite readily during the day [47]. Dispersal of adults is dependent on habitat availability, but it is usually within 300 m from the emergence site [39]. Under laboratory settings with optimal food conditions and at a temperature of 25ºC, a relative humidity of 50%-70%, and a photoperioid of 16L:8D hr, the maximum lifespan of the adults was 101 days for females and 89 days for males [33]. The mean longevity of females was 84.5 ± 10.8 which suggests a high risk for disease transmission [33].

The public health significance of *Ae. japonicus* has been a significant subject matter in recent years. *Aedes japonicus* likely plays a role as a bridge vector in transmission of a number of mosquito-borne viruses to humans and other mammals. In Japan, Takashima and Rosen [57] argued that *Ae. japonicus* may be an important vector of Japanese encephalitis virus in areas where the traditional vector *Culex tritaeniorhynchus* Giles and rice habitats are absent. Takashima and Rosen [57] also demonstrated horizontal and vertical transmission of JE virus by *Ae. japonicus*. Additionally, *Ae. japonicus* is a competent

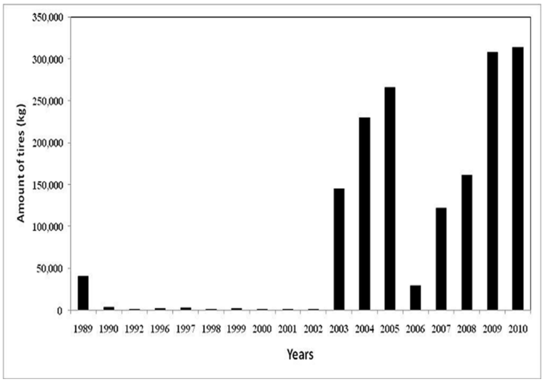

Figure 5. Imports of used tires to Turkey, 1989-2010

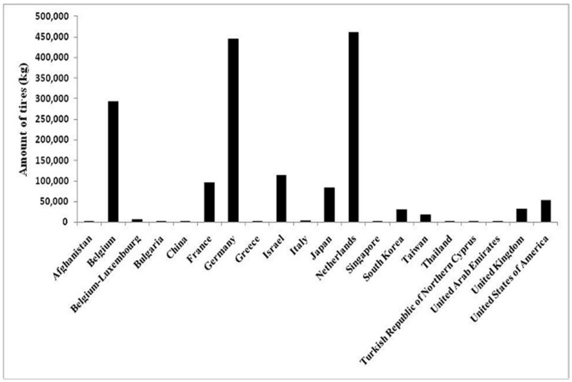

Figure 6. Origin of imported used tires to Turkey, 1989-2010

laboratory vector of WN virus [58,59]. Between 2000 and 2004, WN virus was reported from 69 field-collected pools of *Ae. japonicus* in the United States [60]. In laboratory studies, *Ae. japonicus* has been found to be a competent vector of LaCrosse virus [61], eastern equine encephalitis virus [61], and St. Louis encephalitis virus [62]; however there is no information on natural infection of the species with these viruses from field-collected specimens. Its role as a disease vector species in natural conditions in the United States and Europe, where the species has been firmly established, remains elusive. However, the vectorial capacity of *Ae. japonicus* for multiple established and emerging arboviruses, its rapid spread across the United States since the initial introduction, and a competitive advantage over native species emphasizes the pressing need for implementation of surveillance and control measures for this species.

Adult *Ae. japonicus* are medium to large in size relative to most mosquito species, with a body length of about 10 mm. In their native lands, they are known as Asian bush mosquitoes and prefer sylvan environments and secluded rock pools for larval development [39]. They possess distinctive white basal bands on tarsal leg segments, prominent silvery-white scales on lateral margins on abdominal segments, and distinctive lyre-shaped patterns of golden scales on the scutum (Figure 4).

Both *Ae. albopictus* and *Ae. japonicus* produce desiccation-resistant eggs which tolerate a broad range of environmental conditions and appear to facilitate their introduction into new locales. They have spread successfully to many areas in which they were not previously detected and their superior larval competition adaptabilities, ability to thrive in a wide variety of natural and artificial containers, high population densities, host feeding behaviors, opportunistic/mammalian host preferences, signi-ficant nuisance status, high vectorial capacity for many arboviruses, and considerable public health importance, underscores the importance of these species and their inevitable introduction and impact to susceptible new areas, such as Turkey.

Potential entry routes to Turkey

Turkey reported detection of an invasive *Aedes* species, *Ae. aegypti* during the 1930's [63]. Specimens were collected in southern Turkey, in Istanbul, and along the Black Sea. Additionally, during other surveys conducted between 1959-1962, Curtis [63] also reported three collections of *Ae. aegypti* from Turkey. Those surveys resulted in detection of one adult collection of *Ae. aegypti queenslandensis* in the town of Odemis near the southwest coast of Aegean Sea in 1961 [63]. However, Ramsdale et al. [64] reported *Ae. aegypti* as an extinct species in their revised, annotated checklist of the mosquitoes of Turkey in 2002.

Climate is an important constraint to the establishment of exotic vectors. Coastal areas of Turkey have been identified as having favorable conditions for *Ae. albopictus* [14, 13]. Turkey is at risk from both dispersion of the species and tire imports (Figures 5-8). Turkey has not reported *Ae. albopictus* yet, however it is bordered by countries infested with the species such as Albania, Croatia,

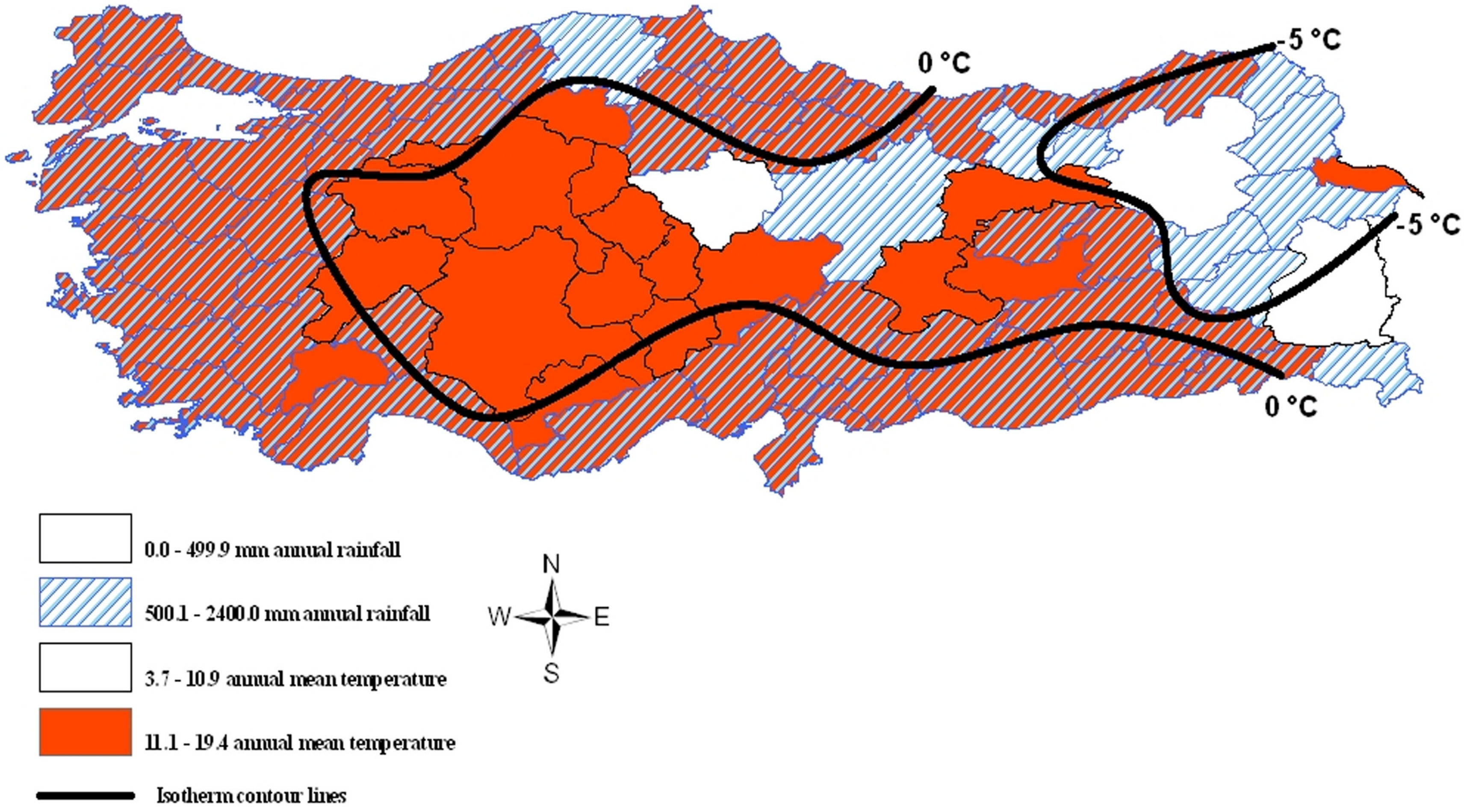

Figure 7. Cities in Turkey receiving more than 500 mm mean rainfall per year and with mean yearly temperatures higher than 11°C. Line represents 0°C and -5 °C monthly mean January temperature isotherms (▬).

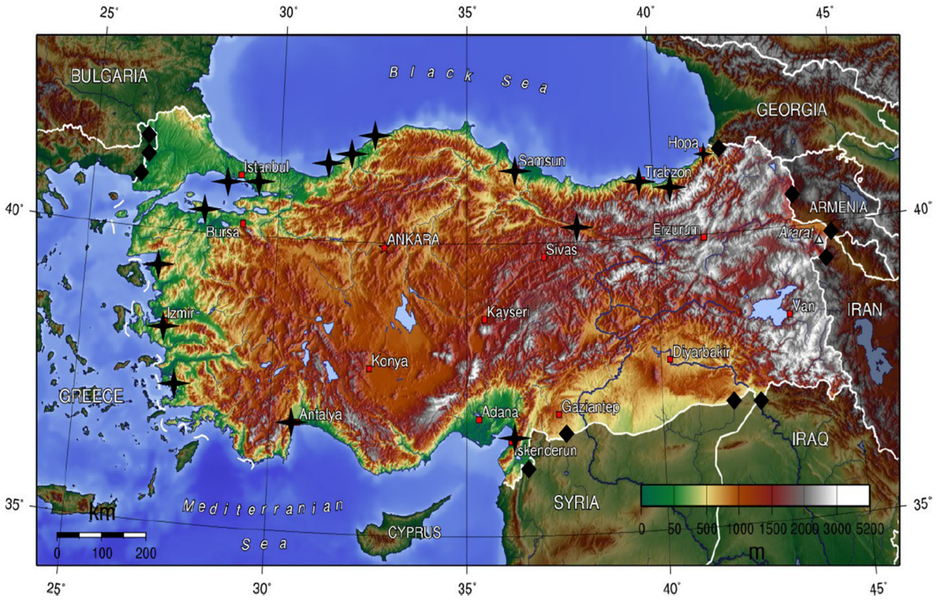

Figure 8. Map of Turkey (elevation based) showing location of ports ( ) and border gates ( ).

and Greece [13]. Annual imports of used tires from 1989 through 2010 are shown in Figure 5. Imports (1989 - 2010) are summarized by country of shipment in Figure 6. During 21 years of imports, 1,627,208 kg of tires were imported from 20 countries. Netherlands provided the largest portion (445.939 kg), followed by Germany (444.620 kg), Belgium (292.695), Israel (114,188 kg), France (95.684), Japan, (82.905 kg) and the United States (52.697 kg). Even though Netherlands regularly reported *Ae. albopictus* in greenhouses in three provinces, there is no evidence of established natural populations of the species [13]. Turkey imported 53.626 kg of used tires from Asian countries during this period from countries where *Ae. albopictus* is indigenous: 82.905 kg were from Japan, 30.990 were from South Korea, 1.680 from China, 17.100 kg were from Taiwan, 1.133 were from Thailand, and 283 kg from Singapore. Turkey also imported 148.460 used tires from France, United States, and Greece after these countries reported successful establishment of *Ae. albopictus*.

Aedes albopictus and *Ae. japonicus* share artificial containers as their larval habitats [65], and researchers monitoring *Ae. albopictus* populations have also discovered *Ae. japonicus* larvae in France [45]. This mosquito probably used the same route of entry with *Ae. albopictus* in tires exported from the United States [45]. It is a very high possibility that *Ae. japonicus* may be introduced to new geographical areas when the conditions are favorable for survival and establishment.

Recently, *Ae. albopictus* have found another mode of entry to new areas using lucky bamboo (*Dracaena sanderiana*) imports. Netherlands has been reporting *Ae. albopictus* mosquitoes in nurseries that imported the ornamental plant lucky bamboo since 2005 [66]. When further investigations were performed, authorities traced mosquitoes back to the southern provinces of Guangdong and Guangxi in China. The Unites States has also been importing lucky bamboo plants from Asia which are transported in 5 to 8 cm of water to keep them green [67]. Turkey does not currently have any history of lucky bamboo importation.

Suitable areas of expansion within Turkey

Climate is also a key factor for the establishment of invasive species in new geographical areas. Using Nawrocki and Hawley's [17] 0°C isotherm estimation for Asia and North America, Mitchell [68] presented an estimation for Europe and concluded that *Ae. albopictus* could become established in European countries as far as the southern coast of Sweden and Norway, and even perhaps in Helsinki, Finland. It has also been reported that *Ae. albopictus* has become established in areas with annual rainfall amounts in excess of 500 mm per year in Europe [20]. Although *Ae. albopictus* is a container-inhabiting mosquito and it may even complete its life cycle in a bottle cap, Mitchell [68] concluded that *Ae. albopictus* is unlikely to become a serious problem in areas with less than 300 mm of rainfall per year. Other climate and environmental variables are also important in determining habitat availability and vast amounts of these variables were considered and examined for European countries in the ECDC [13] report regarding expansion and establishment of *Ae. albopictus*.

In this paper we have plotted the mean annual rainfall rate (Figure 7) and show only areas receiving more than a yearly minimum of 500 mm [68]. In addition to precipitations, we have plotted the mean yearly temperatures higher than 11°C (Figure 7) [69]. Mean monthly temperatures and mean yearly rainfall data between 1970 and 2009 were obtained from the Turkish State Meteorological Service website (http://www.dmi.gov.tr/index.aspx). The blank areas in Figure 7 are defined by < 11 °C all year isotherm and yearly minimum of 500 mm rainfall in order to show potential suitable areas for *Ae. albopictus* establishment. Figure 7 also shows daily mean January temperature isotherms for Turkey. The use of daily mean January temperatures could be utilized to provide a rough estimate of the limits of potential expansion of this species once it is introduced to Turkey. Using the 0°C isotherm, which is a conservative estimate for the limit of the overwintering range, it is apparent that *Ae. albopictus* could become established in major parts of northern, western, and southern Turkey. If we use -5°C isotherm to define the risk areas, the entire country (excluding east) will be sensitive to *Ae. albopictus* invasion since most of the cities meet the < 11°C mean yearly temperatures (one city below 300 mm annual rainfall). Based on these maps, Turkey has higher suitability in the coastal areas and lower suitability in mountainous areas (Figure 7). Considering *Ae. japonicus* larval habitat preference for colder temperatures, mountainous areas might be more suitable for this species, but both may occur readily throughout the proposed range [65].

Turkey currently has 18 major ports and 11 border gates (Figure 8). Most of those ports are located in areas which have favorable climatic conditions for *Ae. albopictus* establishment. Turkey uses the Kapikule border gate (Turkey-Bulgaria) for all international trade, which means used tires from Italy, France, Germany etc. are primarily entering the country through this geographical area (Figure 8). Given the favorable climatic conditions in the western part of Turkey with high levels of international trade through a border gate that is also located in the west, this part of Turkey should be considered at high risk, especially because *Ae. albopictus* has already been established in a neighboring country (Greece).

Future direction for Ae. albopictus and Ae. japonicus in Turkey

Millions of tires are being imported annually from all over the world to various destinations in Europe [5, 45, 70]. It appears that *Ae. albopictus* has been imported in used tires to Europe, probably from the Unites States [71] or Japan, which is the world's major used tire exporter [5]. The association between mosquitoes and tires have a long history that extends back to World War II, when substantial stockpiles of aircraft and military vehicle tires left behind after the war provided suitable habitats for mosquito populations in Europe and the Pacific [72]. It was not until the late 1970's that tires imported from Asia lead to the establishment of *Ae. albopictus* in Europe and then North America [15, 5]. Recently, tires have also been the mode of entry for *Ae. japonicus* from Asia [45], and this trend will likely continue into the future.

As also reported by ECDC [13] certain areas in Turkey are at high risk for *Ae. albopictus* and *Ae. japonicus* invasion and there is currently no species-specific surveillance measures implemented for either species (B. Alten, personal communication). Taking into consideration the lack of organized mosquito control agencies in Turkey, it is a possibility that these species have not been accurately detected yet. This paper may assist the public health authorities and mosquito control agents to quickly identify *Ae. albopictus* and *Ae. japonicus* when they are encountered, thus, allowing for efficient and effective eradication measures such as those displayed in Rowland Hights, California [67] and Indianapolis, Indiana [73]. These studies show that this species may be successfully eliminated, or substantially reduced, presuming if the control program is initiated during the early stages of the infestation [74]. This paper also makes a contribution to strengthen preparedness for the eventual arrival of these species and allows for a better chance to intercept the introduction if it occurs. New Zealand has intercepted *Ae. albopictus* (13 times) and *Ae. japonicus* (10 times) at port cities [70]. It sets a perfect example of the importance of inspection of imported used tires prior to entry to a country. The best means for stopping an invasive species such as *Ae. albopictus* and *Ae. japonicus* is to ensure that these species never enter the country borders.

In conclusion the globalization, international commerce, climate, and geography of Turkey provides a suitable habitat for the introduction and establishment of invasive mosquitoes such as *Ae. albopictus* and *Ae. japonicus*. The quality of life and public health threat from the introduction of these exotic species into Turkey is evident, and proactive measures are needed to identify vectors before local establishment. Vector control is often the only successful means to effectively combat exotic diseases, which emphasizes the critical and timely nature of developing novel surveillance and control measures. Accurate and timely identification of vectors is therefore crucial for initiation of aggressive abatement measures. Most often, governments tend to be reactive rather than proactive, but in the case of vector control, the investments towards a national integrated surveillance and control program are well worth it in the long run. We implore for the establishment of a national vector surveillance program which would allow for prompt recognition of introduced species in expanding ranges, particularly in the larval stage when targeted abatement efforts would be most efficient to eliminate or curb their expansion.

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