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Rapid Communication

Reported Distribution of *Aedes* (*Stegomyia*) *aegypti* and *Aedes* (*Stegomyia*) *albopictus* in the United States, 1995-2016 (Diptera: Culicidae)

Micah B. Hahn,[1] Rebecca J. Eisen,[1] Lars Eisen,[1] Karen A. Boegler,[1] Chester G. Moore,[2] Janet McAllister,[1] Harry M. Savage,[1] and John-Paul Mutebi[1,3]

[1]Division of Vector-Borne Diseases, Centers for Disease Control and Prevention, 3156 Rampart Road, Fort Collins, Colorado 80521 (xht1@cdc.gov; dyn2@cdc.gov; hms1@cdc.gov; kje5@cdc.gov; evp4@cdc.gov; jvm6@cdc.gov; grv0@cdc.gov) [2]Department of Microbiology, Immunology and Pathology, Colorado State University, 3195 Rampart Road, Fort Collins, Colorado 80523 (Chester.Moore@ColoState.edu), and [3]Corresponding author, e-mail: grv0@cdc.gov.

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Abstract

Aedes (*Stegomyia*) *aegypti* (L.) and *Aedes* (*Stegomyia*) *albopictus* (Skuse) transmit arboviruses that are increasing threats to human health in the Americas, particularly dengue, chikungunya, and Zika viruses. Epidemics of the associated arboviral diseases have been limited to South and Central America, Mexico, and the Caribbean in the Western Hemisphere, with only minor localized outbreaks in the United States. Nevertheless, accurate and up-to-date information for the geographical ranges of *Ae. aegypti* and *Ae. albopictus* in the United States is urgently needed to guide surveillance and enhance control capacity for these mosquitoes. We compiled county records for presence of *Ae. aegypti* and *Ae. albopictus* in the United States from 1995-2016, presented here in map format. Records were derived from the Centers for Disease Control and Prevention ArboNET database, VectorMap, the published literature, and a survey of mosquito control agencies, university researchers, and state and local health departments. Between January 1995 and March 2016, 183 counties from 26 states and the District of Columbia reported occurrence of *Ae. aegypti*, and 1,241 counties from 40 states and the District of Columbia reported occurrence of *Ae. albopictus*. During the same time period, *Ae. aegypti* was collected in 3 or more years from 94 counties from 14 states and the District of Columbia, and *Ae. albopictus* was collected during 3 or more years from 514 counties in 34 states and the District of Columbia. Our findings underscore the need for systematic surveillance of *Ae. aegypti* and *Ae. albopictus* in the United States and delineate areas with risk for the transmission of these introduced arboviruses.

Key words: *Aedes aegypti*, *Aedes albopictus*, surveillance, distribution, United States

Arboviruses transmitted by the yellow fever mosquito, *Aedes* (*Stegomyia*) *aegypti* (L.), and the Asian tiger mosquito, *Aedes* (*Stegomyia*) *albopictus* (Skuse), are increasing threats to human health in the Americas. The re-emergence of dengue viruses in the Western Hemisphere during the 1980s and 1990s was followed by the emergence of chikungunya virus in 2013 and Zika virus in 2015 (Brathwaite et al. 2012, Weaver and Forrester 2015, Zanluca et al. 2015). Epidemics of dengue, chikungunya, and now Zika have swept through or are sweeping through South America, Central America, Mexico, and the Caribbean (San Martín et al. 2010, Johansson et al. 2014, Hennessey et al. 2016). Yellow fever virus remains a concern with sporadic yellow fever outbreaks in South America (Barrett and Higgs 2007, Gardner and Ryman 2010).

Both *Ae. aegypti* and *Ae. albopictus* are established in the United States (Darsie and Ward 2005, Kraemer et al. 2015). *Aedes aegypti* most likely has been present, permanently or intermittently, in the southeastern United States since the 17th century and is the suspected vector of the yellow fever and dengue outbreaks that occurred in the eastern part of the country from 1650 to the early 20th century (Eisen and Moore 2013). A multi-state survey in 1964 showed this mosquito to still be present in 203 counties across 10 states in the Southeast (Morlan and Tinker 1965). Recently, *Ae. aegypti* has become established in the Southwest, including Arizona and California, and is sporadically reported from Mid-Atlantic states and Washington, D.C. (Eisen and Moore 2013, Kraemer et al. 2015, Porse et al. 2015, Lima et al. 2016). The first established population of *Ae. albopictus* in the continental United States was recorded from Texas in 1985 (Sprenger and Wuithiranyagool 1986). The mosquito thereafter spread rapidly across the Southeast to later reach the southern portions of the Northeast and Upper Midwest as well as the Pacific Coast (Moore 1999, Kraemer et al. 2015, Porse et al. 2015). Both mosquito species are at the northern limits of their

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geographical ranges in the continental United States, but the range of *Ae. albopictus* is much broader; it exists as both tropical and temperate populations (Nawrocki and Hawley 1987), and it is capable of establishing overwintering populations farther north compared with *Ae. aegypti* (Darsie and Ward 2005, Kraemer et al. 2015).

The emerging threats of dengue, chikungunya, and Zika virus diseases have highlighted the need for accurate and up-to-date records for the geographical ranges of *Ae. aegypti* and *Ae. albopictus* to guide ongoing efforts to strengthen mosquito surveillance and control capacity (World Health Organization 2009, PAHO / CDC 2011), and to serve as the basis for model-based predictions of future spread of these important arbovirus vectors. We therefore have compiled county records for presence of *Ae. aegypti* and *Ae. albopictus* in the United States from 1995 to 2016. These data were used to develop contemporary county-scale distribution maps of each species.

Materials and Methods

Selection of Time Period and Criteria for Mosquito Presence Classifications

We included collection records from 1995 to the present (March 2016, henceforth referred to as 2016) from several primary and secondary data sources to identify counties that have reported contemporary collections of *Ae. aegypti* or *Ae. albopictus* and thus likely represent the current distributions of these mosquitoes. *Aedes aegypti* or *Ae. albopictus* was considered "present" in a county in a given calendar year if at least one specimen of any life stage of the mosquito was collected, using any collection method, during that year. We further classified counties with reported *Ae. aegypti* or *Ae. albopictus* based on whether a species was collected in 1, 2, or 3 or more years, with no distinction of whether or not collection years were consecutive. This was done to distinguish between counties in which *Ae. aegypti* or *Ae. albopictus* were collected in a single year and counties where these mosquito species have been reported in multiple years between 1995 and 2016, indicating either established populations or introduction of the species in more than one year. A county was classified as having "no reported records" for a species if there were no collection records for that species between 1995 and 2016. However, a classification of no reported records for a county should not necessarily be interpreted as the given species being absent in that county.

Compilation of Preexisting Collection Records

We extracted records for reported occurrence of *Ae. aegypti* or *Ae. albopictus* between 2000 and 2015 in the United States from the Centers for Disease Control and Prevention (CDC) ArboNET surveillance system database, which was established in 2000 following the introduction of West Nile virus to the United States in 1999 (Centers for Disease Control and Prevention 2014). Additional mosquito surveillance records for 2015 may be entered into the surveillance system for the next few weeks, as the 2015 data are still provisional, but we extracted all available records for 2015 that were in the database as of 10 March 2016. ArboNET is the national surveillance database maintained by the CDC for nationally notifiable arboviral diseases. In addition to human cases of arboviral disease, state health departments can voluntarily report data for virus infection in birds and domestic animals and for collected and/or tested mosquitoes. The ArboNET records for mosquitoes include the county and date of collection. We also extracted collection records for *Ae. aegypti* or *Ae. albopictus* between 1995 and 1 March 2016 from VectorMap, an open-source, online database of global geo-referenced mosquito collection records managed by the Walter Reed Biosystematics Unit in the Smithsonian Institution (Foley et al. 2016). In addition, we extracted collection records between 1995 and 2014 in the United States from Kraemer et al. (2015). Kraemer et al. (2015) presented a global compendium of *Ae. aegypti* and *Ae. albopictus* records from 1960 to 2014 from peer-reviewed literature and unpublished sources such as national entomological surveys and expert networks.

We also performed literature searches in PubMed and Scopus using the search terms "*Aedes aegypti*" or "*Aedes albopictus*" or "*Stegomyia*" and "United States" between 1 January 2013 and 7 March 2016 to identify collection records that were too recent to be included by Kraemer et al. (2015). We limited the language to English. Records were included in our database if the descriptions of collection location and time period in the article allowed for determination of county and year of collection and if that collection year was in 1995 or later. Full references for each published record in the final database are included in Supplementary Tables 1 and 2.

Survey for Additional Collection Records

We also designed an online survey, using GoogleForms, to compile additional county-level collection records for *Ae. aegypti* and *Ae. albopictus* in the United States between 2000 and 2016, corresponding to the time period data were captured in ArboNET. The survey was designed to capture contemporary surveillance records from vector control districts, university researchers, and local health departments that were not submitted to ArboNET, which is designed to collect information only from state health departments. A cover letter explained the purpose of the project and asked for voluntary contributions of collection records for these two mosquito species. The link to the online survey was widely disseminated to stakeholders with the aid of the Entomological Society of America (ESA), the American Mosquito Control Association (AMCA), the National Association of Vector-Borne Disease Control Officials (NAVCO), the Society for Vector Ecology (SOVE), the American Society of Tropical Medicine and Hygiene (ASTMH), the National Association of County and City Health Officials (NACCHO), and the National Pesticide Information Center (NPIC). We also contacted individual mosquito researchers as well as commercial mosquito control companies and local mosquito control organizations, such as the Florida Mosquito Control Association, which publishes *WingBeats*, a widely read periodical for mosquito control professionals.

The survey tool compiled contact and affiliation information for the person entering records, as well as county-level records by year for *Ae. aegypti* or *Ae. albopictus*. If no records were reported for one or both species in the county, respondents had the option to check a box to indicate the absence of collection records. However, given the lack of systematic sampling efforts, locations of absence data are not shown on our maps. The survey opened 8 February 2016 and responses were requested by 1 March 2016, but the survey tool was available beyond that date. Responses reported here extend through 16 March 2016.

Management of Collection Record Database

Because our database was compiled from multiple data sources, we standardized the spatial scale and time period of the collection records. Kraemer et al. (2015) geocoded each of the collection locations either with a latitude and longitude or as the centroid of a larger polygon when finer-scale geo-location was not possible.

We extracted their records that occurred in the United States between 1995 and 2014, and then we spatially joined each record to the county that contained its x, y coordinates. If the record was identified as either the centroid of a county polygon or coordinates from an exact collection location in their database, we included it in our database. For records where the coordinates were obtained through other matching methods, we reviewed the original citation to verify that the coordinates were matched to the appropriate county. We followed a similar methodology for extracting the relevant mosquito collection locations from the VectorMap database between 1995 and 2016 and linking them to a county. The ArboNET data were already at the county scale.

We then generated two datasets, one that contained all the *Ae. aegypti* collection records and one with all of the *Ae. albopictus* collection records. These datasets contained the county and year of mosquito collection. To avoid duplicates, we extracted only one record for each county in a given year for each mosquito species. Finally, we calculated the number of years of collection records reported for each county for each species and used the resulting county-level databases of collection records for *Ae. aegypti* and *Ae. albopictus* to join the county data by FIPS codes in ArcGIS 10.3 (ESRI, Redlands, CA) and map the number of years each species has been reported by county.

Results

Number of Counties and States With Reported Occurrence of *Aedes aegypti*

Between 1 January 1995 and 31 December 1999, occurrence of *Ae. aegypti* was reported from 11 counties in Arizona, Texas, and Florida (Fig. 1a) . By 2004, occurrence of *Ae. aegypti* was reported from 80 counties (Fig. 1b) and records were added along the southern tier as well as sporadically along the East coast. Notably, by 2004, records of *Ae. aegypti* were being reported in the Mid-Atlantic region focused around Washington, D.C. By 2009, the number of counties from which the occurrence of *Ae. aegypti* was reported had increased to 109 (Fig. 1c), but the reported geographic distribution of the mosquito had not changed appreciably. Between 1 January 1995 and March 2016, occurrence of *Ae. aegypti* was reported from 183 counties in 26 states and the District of Columbia (Fig. 1d). During the same time period, *Ae. aegypti* was collected in 3 or more years from 94 counties from 14 states and the District of Columbia (Fig. 1d). Since 1995, *Ae. aegypti* has been documented along much of the southern tier of the United States, including southern California, Arizona, New Mexico, Texas, Louisiana, and Florida. There also have been sporadic collections of *Ae. aegypti* from other parts of the Southeast and the Mid-Atlantic states, as well as in geographic outliers in Colorado, Kansas, Michigan, and New Hampshire.

Number of Counties and States With Reported Occurrence of *Aedes albopictus*

Between 1 January 1995 and 31 December 1999, occurrence of *Ae. albopictus* was reported from 370 counties (Fig. 2a). During this time period, *Ae. albopictus* was documented predominately in the southeastern United States, but with reported records as far west as Kansas, Oklahoma, and Texas and as far north as New Jersey. By 2004, occurrence of *Ae. albopictus* was reported from 973 counties (Fig. 2b). Collection records for *Ae. albopictus* increased substantially during this time period, expanding the documented distribution in the Southeast, South Central, and Mid-Atlantic states as well as southern Illinois, Indiana, and Ohio. By this time, records were reported as far north as Massachusetts, New York, and New Hampshire. In addition, *Ae. albopictus* had been introduced to southern California several times via cargo shipments from the South Pacific region by 2004, but in 2001, a shipment from China of infested "lucky bamboo" resulted in 15 local infestations in six counties in the region (Zhong et al. 2013). By 2009, the number of counties in which occurrence of *Ae. albopictus* was reported had increased to 1,093 (Fig. 2c). Other than documenting the presence of the *Ae. albopictus* in Arizona and New Mexico, the reported distribution of the mosquito did not change substantially during this time period. Additional records were reported along the East Coast, southern Indiana, and Missouri. Between 1 January 1995 and March 2016, occurrence of *Ae. albopictus* was reported from 1,241 counties from 40 states and the District of Columbia (Fig. 2d). During the same time period, *Ae. albopictus* was collected during 3 or more years from 514 counties in 34 states and the District of Columbia (Fig. 2d). *Ae. albopictus* has been consistently reported from most of the Southeast, South Central, and Mid-Atlantic states as well as along the southern Ohio River Valley. Reports for *Ae. albopictus* are more sporadic in the western United States than *Ae. aegypti*, but there have been consistent reports of the mosquito from southern California and southwestern Arizona.

Discussion

Collection records of *Ae. aegypti* from 1 January 1995 to March 2016 are concentrated in Florida, Texas, Arizona, and California, with more sporadic records in the Southern, Mid-Atlantic, and Midwestern states. A previous extensive multi-state surveillance effort conducted in 1964 in preparation of a planned *Ae. aegypti* eradication program showed that this mosquito was widely distributed across the southeastern United States at that time (Morlan and Tinker 1965). The program to eradicate *Ae. aegypti* from the continental United States never reached its ultimate goal and was terminated in 1969 due to lack of funds (Slosek 1986). No subsequent surveillance effort in the United States has come close to rivaling the intensity of the 1964 survey for *Ae. aegypti*. Sporadic contemporary collections of *Ae. aegypti* along the mid-Atlantic Coast are not surprising, as this mosquito historically caused yellow fever outbreaks as far north as New York and Boston (Patterson 1992, Reiter 2001). Perhaps the most concerning development for *Ae. aegypti* is its establishment in the Southwest, most recently in California in 2013. The discovery of established populations of *Ae. aegypti* in central and southern California resulted in a substantial, and still ongoing, public health response that has included enhanced human and mosquito surveillance, education, and intensive mosquito control (Porse et al. 2015).

Records for *Ae. albopictus* from 1 January 1995 to March 2016 show that this mosquito covers similar areas in the western United States as *Ae. aegypti* but has a much wider geographic distribution in the East, reaching as far north as Illinois, Ohio, and Pennsylvania and the New England coast. It is not clear whether this recent invader, which was introduced into the United States in 1985 and in several subsequent introductions (Moore et al. 1988, Moore 1999, Kuno 2012), has yet to become established across the full geographical range within which it can persist or if it is still expanding its range. Although the climate in some newly invaded areas is conducive to reproduction and survival of this mosquito, in other areas, harsh winters may prevent survival of overwintering eggs into the spring. In addition, effective and timely vector control may eliminate highly localized introductions, for example, in tire facilities.

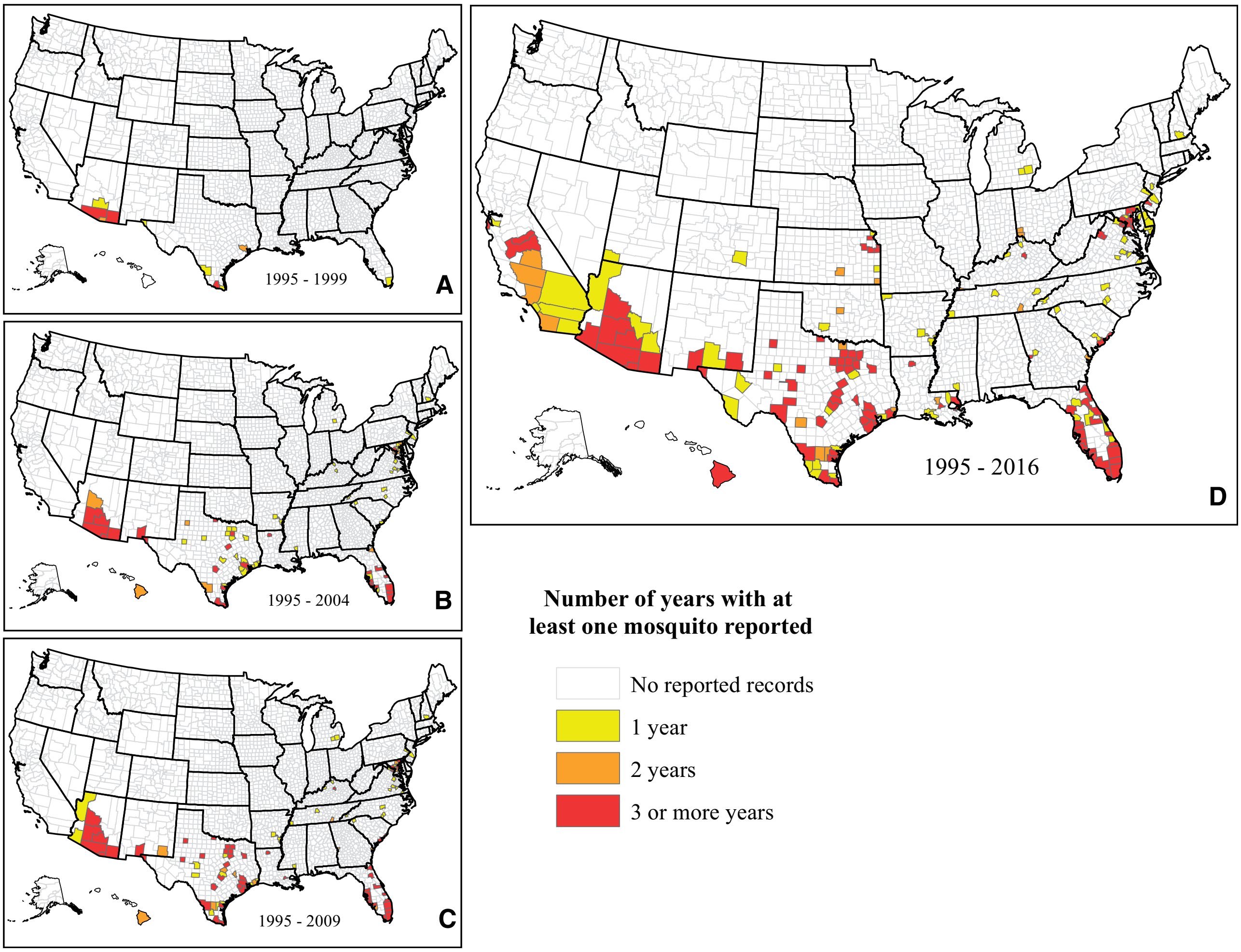

Fig. 1. Maps showing the reported occurrence of *Ae. aegypti* by county between 1 January 1995 and March 2016 in the United States. (A) Reported occurrence from 1 January 1995 through 1999, (B) reported occurrence from 1 January 1995 through 2004, (C) reported occurrence from 1 January 1995 through 2009, and (D) reported occurrence from 1 January 1995 through March 2016, representing the best knowledge of the current distribution of this mosquito based on collection records. Counties shown in white had no reported *Ae. aegypti* presence records within the specified time period. Counties shown in yellow had *Ae. aegypti* presence records for 1 year within the specified time period, those shown in orange had 2 years of presence records within the specified time period, and those shown in red had 3 or more years of presence records within the specified time period.

The county records for *Ae. aegypti* and *Ae. albopictus* presented here represent our best knowledge of the current distributions of these mosquitoes, but we caution that, at the national scale, the presented data should be viewed as compilations of records based on convenience sampling rather than representing systematic surveys. Particularly between 1995 and 2004, the substantial increase in the number of counties reporting these two species is likely due, in large part, to an increase in surveillance rather than expansion of the geographic distribution of the mosquitoes. Moreover, these data represent presence rather than abundance of the mosquitoes, and it should not be assumed that the climate across counties in which the mosquitoes are present provides similar potential for population establishment and expansion. Areas of interest for enhanced *Ae. aegypti* surveillance include states in which it is firmly established (Florida, Texas, Arizona and California) as well as New Mexico, the other Gulf Coast states, and the Atlantic Coast states where it was present historically. Areas of interest for enhanced *Ae. albopictus* surveillance include the northern range margins across the country as well as states with less than expected coverage based on records for surrounding states such as Georgia, Arkansas, and Kentucky. Ideally, surveillance programs should include the collection of both vector distribution and vector abundance data, as measured by repeated and regular use of standardized collection methods such as the BG-Sentinel trap (Biogents, Germany) or ovicups (Focks 2003). Vector abundance data would be essential to evaluate source reduction and other larval control efforts and to provide thresholds for adulticide applications. Intensive surveillance in response to a potential or known introduction of an *Ae. (Stegomyia)*-vectored virus such as Zika virus or a dengue virus (e.g., in response to the investigation of a suspect or established locally acquired case or successful virus introduction) should include virus testing of mosquito pools to verify local transmission and to determine the infection rate to direct and evaluate vector control operations (Centers for Disease Control and Prevention 2016).

Lack of collection records for *Ae. aegypti* or *Ae. albopictus* from a given county should not be interpreted as absence of that mosquito, especially if the mosquito has been collected from nearby areas. Conversely, collection records from a county does not necessarily imply that the mosquito is present throughout that county, especially for large and climatically diverse counties in the western United States. Moreover, counties that have 3 or more years of collection records for a given species do not necessarily have established

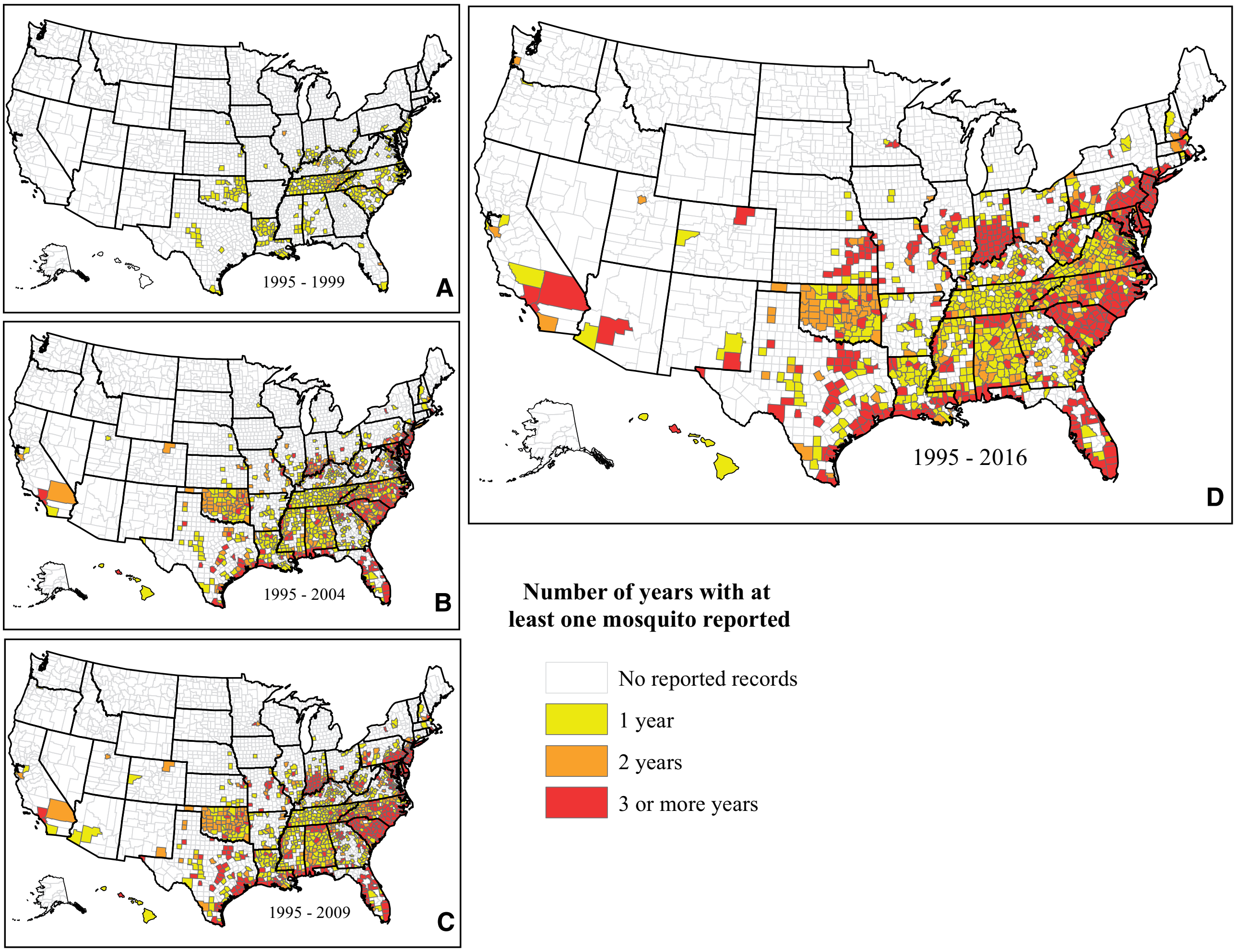

Fig. 2. Maps showing the reported occurrence of *Ae. albopictus* by county between 1 January 1995 and March 2016 in the United States. (A) Reported occurrence from 1 January 1995 through 1999, (B) reported occurrence from 1 January 1995 through 2004, (C) reported occurrence from 1 January 1995 through 2009, and (D) reported occurrence from 1 January 1995 through March 2016, representing the best knowledge of the current distribution of this mosquito based on collection records. Counties shown in white had no reported *Ae. albopictus* presence records within the specified time period. Counties shown in yellow had *Ae. albopictus* presence records for 1 year within the specified time period, those shown in orange had 2 years of presence records within the specified time period, and those shown in red had 3 or more years of presence records within the specified time period.

populations of that species. For example, extreme outliers to the north (e.g., Minnesota) or in the central, intermountain west (e.g., Colorado) for both species are commonly associated with repeated introductions to tire facilities (Reiter 1998, Bennett et al. 2005, Neitzel et al. 2009). Finally, based on differences in the intensity and spatial coverage of the surveillance effort and the collection methods used, our maps showing collection records of *Ae. aegypti* or *Ae. albopictus* from 1 January 1995 to March 2016 should not be viewed as directly comparable with maps that include data from earlier time periods (Morlan and Tinker 1965, Moore 1999, Darsie and Ward 2005, Eisen and Moore 2013, Kraemer et al. 2015).

Due to their unique biology, the container-inhabiting, day-active, and predominantly human-biting *Ae. aegypti* are only rarely collected in surveillance efforts that target *Culex* vectors of West Nile virus or non-container breeding *Aedes* mosquitoes. The intensified surveillance for mosquitoes and mosquito-borne viruses that resulted from the 1999 introduction of West Nile virus to the United States therefore had very limited potential for generating data for the occurrence of *Ae. aegypti* and *Ae. albopictus*. Nonetheless, occasional records of *Ae. aegypti* and *Ae. albopictus* were reported to ArboNET and are reported here. Appropriate surveillance for *Ae. aegypti* and *Ae. albopictus* can include the passive collection of eggs from ovitraps, active collection of larvae or pupae from artificial containers and water-holding tree holes or other water-holding plants, passive collection of adults using *Stegomyia*-appropriate traps (e.g., the BG-Sentinel trap for females seeking a bloodmeal host, or a gravid trap for females seeking an artificial container in which to lay their eggs), or active collection of adults during the day using mechanical aspirators (World Health Organization 2009). Because of their close association with humans, surveillance for *Ae. aegypti* should be conducted near human dwellings, for example, by placing traps just outside homes or schools, by collecting larvae and pupae from artificial containers near homes or in other key container-rich environments (e.g., tire dumps and cemeteries), and by aspiration of adults near home entry points. Surveillance for *Ae. albopictus* needs to be much broader because this species is found both near and far from human dwellings.

Other considerations for surveillance of *Ae. aegypti* and *Ae. albopictus* include subtle differences in the biology of these mosquitoes and between-species competition for container habitats. In settings where the number of containers available for oviposition is limited, *Ae. albopictus* immatures can under some circumstances outcompete *Ae. aegypti* (Juliano 2010), potentially leading to local disappearance of *Ae. aegypti*. Perhaps more important from a surveillance standpoint, these two mosquitoes tend to segregate in their habitat choices, with *Ae. aegypti* being more common in high-density urban settings and *Ae. albopictus* predominating in lower-density urban and semirural settings, although in some areas, these two species have been found to coexist in urban areas (Leisnham and Juliano 2009, Reiskind and Lounibos 2013, Leisnham et al. 2014). This spatial and temporal variability needs to be accounted for if a surveillance program aims to capture high-quality data for both *Ae. aegypti* and *Ae. albopictus*. And although some artificial breeding sites such as tires or planters are exploited by some *Culex* spp. as well as *Ae. aegypti* and *Ae. albopictus*, it also should be noted that surveillance for some *Culex* vectors of West Nile virus, such as *Culex tarsalis* Coquillett and *Culex nigripalpus* (Theobald), often targets open water larval development sites located in natural habitats not frequented by *Ae. aegypti* and *Ae. albopictus*. When trap grids are established for surveillance of *Culex* adults, specific trap locations are chosen to maximize trap catches based on presence of *Culex* larval development sites and perceived dispersal corridors from those emergence sites, again leading to low potential for collection of *Ae. aegypti* and *Ae. albopictus*.

Although the presence of *Ae. aegypti* and *Ae. albopictus* sets the stage for local arbovirus transmission, other factors limit the potential for transmission of dengue, chikungunya, yellow fever, and Zika viruses in the United States. Factors that reduce the intensity of transmission of arboviruses by *Ae. aegypti* and *Ae. albopictus* in the continental United States include 1) less than optimal temperatures during much of the year restricting the potential for mosquito population growth compared with settings where they can proliferate year-round; 2) well-developed sanitation services and reliable access to piped water reducing accumulation of water-storage containers serving as larval development sites; 3) high-quality housing, air-conditioning, and use of screens and doors that prevent entry of *Ae. aegpyti* and *Ae. albopictus* females into buildings and thus reduce human-mosquito contact; 4) capacity for rapid detection of human disease cases as well as timely mosquito-based virus surveillance to facilitate early mosquito control response; and 5) availability of financial resources for rapid, intensive response to localized outbreaks (Halstead 2008, Gubler 2011, Eisen et al. 2014, Monaghan et al. 2016).

From a historical perspective, *Ae. aegypti* most likely was the primary vector in major epidemics of yellow fever and dengue that occurred across the eastern United States during the 18th and 19th centuries. These epidemics ceased in the 20th century, most likely due to changes to ship design and sailing patterns, urban improvements (particularly to piped water supplies), increasing use of window screens, and, following the realization in 1900 that a mosquito transmits the causative agent of yellow fever, mosquito control efforts (Patterson 1992, Reiter 2001, Eisen and Moore 2013). Following a long period without recognized endemic dengue virus transmission in the continental United States, small outbreaks of autochthonous dengue occurred in southern Texas in 2004 and 2005 and southern Florida from 2009 to 2011 (Brunkard et al. 2007, Adalja et al. 2012, Radke et al. 2012). During the chikungunya outbreak in the Western Hemisphere in 2013 and 2014, 11 autochthonous cases of the disease were identified in Florida (Kendrick et al. 2014). Despite these limited examples of local transmission, large outbreaks of arboviruses transmitted by *Ae. aegypti* and *Ae. albopictus* are unlikely to recur in the continental United States unless socioeconomic conditions deteriorate to mimic those seen in previous centuries or if other modes of transmission for these viruses became more widespread (Foy et al. 2011, Musso et al. 2015).

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Supplementary Data

Supplementary data are available at *Journal of Medical Entomology* online.

References

Adalja, A. A., T. K. Sell, N. Bouri, and C. Franco. 2012. Lessons learned during dengue outbreaks in the United States, 2001-2011. Emerg. Infect. Dis. 18: 608–614.

Barrett, A. D., and S. Higgs. 2007. Yellow fever: A disease that has yet to be conquered. Annu. Rev. Entomol. 52: 209–229.

Bennett, J., A. Hickman, M. Kline, M. McGinnis, and M. Weissmann. 2005. New state record for the Asian tiger mosquito, *Aedes albopictus* (Skuse). J. Am. Mosq. Control Assoc. 21: 341–343.

Brathwaite, O., J. L. San Martín, R. H. Montoya, J. del Diego, B. Zambrano, and G. H. Dayan. 2012. The history of dengue outbreaks in the Americas. Am. J. Trop. Med. Hyg. 87: 584–593.

Brunkard, J. M., J. L. Robles Lopez, J. Ramirez, E. Cifuentes, S. J. Rothenberg, E. A. Hunsperger, C. G. Moore, R. M. Brussolo, N. A. Villarreal, and B. M. Haddad. 2007. Dengue fever seroprevalence and risk factors, Texas-Mexico border, 2004. Emerg Infect Dis. 13: 1477–1483.

Centers for Disease Control and Prevention. 2014. ArboNET Database. (http://www.cdc.gov/westnile/resourcepages/survResources.html) last accessed 15 March 2015.

Centers for Disease Control and Prevention. 2016. Surveillance and control of *Aedes aegypti* and *Aedes albopictus* in the United States. (http://www.cdc.gov/chikungunya/resources/vector-control.html) last accessed 15 March 2016.

Darsie, R., and R. Ward. 2005. Identification and Geographical Distribution of the Mosquitoes of North America, North of Mexico. University Press of Florida, Gainesville, FL.

Eisen, L., and C. G. Moore. 2013. *Aedes* (*Stegomyia*) *aegypti* in the continental United States: A vector at the cool margin of its geographic range. J. Med. Entomol. 50: 467–478.

Eisen, L., A. J. Monaghan, S. Lozano-Fuentes, D. F. Steinhoff, M. H. Hayden, and P. E. Bieringer. 2014. The impact of temperature on the bionomics of *Aedes* (*Stegomyia*) *aegypti*, with special reference to the cool geographic range margins. J. Med. Entomol. 51: 496–516.

Focks, D. 2003. A review of entomological sampling methods and indicators for dengue vectors. World Health Organization, Geneva, Switzerland.

Foley, D., P. Rueda, and R. Wilkerson. 2016. VectorMap. Walter Reed Biosyst. Unit. (http://vectormap.si.edu/index.htm) last accessed 15 March 2016.

Foy, B. D., K. Kobylinski, J. Foy, B. Blitvich, A. Travossos da Rosa, A. Haddow, R. Lanciotti, and R. Tesh. 2011. Probable non-vector-borne transmission of Zika virus, Colorado USA. Emerg. Infect. Dis. 17.

Gardner, C. L., and K. D. Ryman. 2010. Yellow fever: a reemerging threat. Clin. Lab. Med. 30: 237–260.

Gubler, D. J. 2011. Dengue, urbanization and globalization: The unholy trinity of the 21 st century. Trop. Med. Health. 39: S3–S11.

Halstead, S. B. 2008. Dengue virus-mosquito interactions. Annu. Rev. Entomol. 53: 273–291.

Hennessey, M., M. Fischer, and J. E. Staples. 2016. Zika virus spreads to new areas –region of the Americas, May 2015–January 2016. Morb. Mortal. Wkly. Rep. 65: 55–58.

Johansson, M. A., A. M. Powers, N. Pesik, N. J. Cohen, and J. E. Staples. 2014. Nowcasting the spread of chikungunya virus in the Americas. PLoS ONE 9: e104915.

Juliano, S. A. 2010. Coexistence, exclusion, or neutrality? A meta-analysis of competition between *Aedes albopictus* and resident mosquitoes. Isr. J. Ecol. Evol. 56: 325–351.

Kendrick, K., D. Stanek, and C. Blackmore. 2014. Notes from the Field: Transmission of chikungunya virus in the continental United States — Florida, 2014. Morb. Mortal. Wkly. Rep. 63: 1137.

Kraemer, M. U., M. E. Sinka, K. A. Duda, A. Mylne, F. M. Shearer, O. J. Brady, J. P. Messina, C. M. Barker, C. G. Moore, R. G. Carvalho, G. E. Coelho. 2015. The global compendium of *Aedes aegypti* and *Ae. albopictus* occurrence. Scientific Data 2: 150035.

Kuno, G. 2012. Revisiting Houston and Memphis: The background histories behind the discovery of the infestation by *Aedes albopictu*s (Diptera: Culicidae) in the United States and their significance in the contemporary research. J. Med. Entomol. 49: 1163–1476.

Leisnham, P. T., and S. A. Juliano. 2009. Spatial and temporal patterns of coexistence between competing *Aedes* mosquitoes in urban Florida. Oecologia 160: 343–352.

Leisnham, P. T., S. L. LaDeau, and S. A. Juliano. 2014. Spatial and temporal habitat segregation of mosquitoes in urban Florida. PLoS ONE 9: e91655.

Lima, A., D. D. Lovin, P. V Hickner, and D. W. Severson. 2016. Evidence for an overwintering population of *Aedes aegypti* in Capitol Hill neighborhood, Washington, DC. Am. J. Trop. Med. Hyg. 94: 231–235.

Moore, C. 1999. *Aedes albopictus* in the United States: Current status and prospects for further spread. J. Am. Mosq. Control Assoc. 15: 221–227.

Moore, C., D. Francy, D. Eliason, and T. Monath. 1988. *Aedes albopictus* in the United States: Rapid spread of a potential disease vector. J. Am. Mosq. Control Assoc. 4: 356–361.

Morlan, H. B., and M. E. Tinker. 1965. Distribution of *Aedes aegypti* infestations in the United States. Am. J. Trop. Med. Hyg. 14: 892–899.

Musso, D., C. Roche, E. Robin, T. Nhan, A. Teissier, and V. Cao-Lormeau. 2015. Potential sexual transmission of Zika virus. Emerg. Infect. Dis. 2: 359–361.

Nawrocki, S., and W. Hawley. 1987. Estimation of the northern limits of distribution of *Aedes albopictus* in North America. J. Am. Mosq. Control Assoc. 3: 314–317.

Neitzel, D. F., K. A. Johnson, S. Brogren, and M. M. Kemperman. 2009. First collection records of *Aedes japonicus* in Minnesota. J. Am. Mosq. Control Assoc. 25: 367–369.

PAHO / CDC. 2011. Preparedness and response for chikungunya virus: Introduction in the Americas. Pan American Health Organization, Washington, DC.

Patterson, K. D. 1992. Yellow fever epidemics and mortality in the United States, 1693–1905. Soc. Sci. Med. 34: 855–865.

Porse, C. C., V. Kramer, M. H. Yoshimizu, M. Metzger, R. Hu, K. Padgett, and D. J. Vugia. 2015. Public health response to *Aedes aegypti* and *Ae. albopictus* mosquitoes invading California, USA. Emerg. Infect. Dis. 21: 1827.

Radke, E. G., C. J. Gregory, K. W. Kintziger, E. K. Sauber-Schatz, E. A. Hunsperger, G. R. Gallagher, J. M. Barber, B. J. Biggerstaff, D. R. Stanek, K. M. Tomashek, et al. 2012. Dengue outbreak in Key West, Florida, USA, 2009. Emerg Infect Dis. 18: 135–137.

Reiskind, M. H., and L. P. Lounibos. 2013. Spatial and temporal patterns of abundance of *Aedes aegypti* L. (*Stegomyia aegypti*) and *Aedes albopictus* (Skuse) (*Stegomyia albopictus* (Skuse)) in southern Florida. Med. Vet. Entomol. 27: 421–429.

Reiter, P. 1998. *Aedes albopictus* and the world trade in used tires, 1988-1995: The shape of things to come? J. Am. Mosq. Control Assoc. 14: 83–94.

Reiter, P. 2001. Climate change and mosquito-borne disease. Environ. Health Perspect. 109: 141–161.

San Martín, J. L., O. Brathwaite, B. Zambrano, J. O. Solozrano, A. Bouckenooghe, G. H. Dayan, and M. G. Guzman. 2010. The epidemiology of dengue in the Americas over the last three decades: A worrisome reality. Am. J. Trop. Med. Hyg. 82: 128–135.

Slosek, J. 1986. Aedes aegypti mosquitoes in the Americas: A review of their interactions with the human population. Soc. Sci. Med. 23: 249–257.

Sprenger, D., and T. Wuithiranyagool. 1986. The discovery and distribution of *Aedes albopictus* in Harris County, Texas. J. Am. Mosq. Control Assoc. 2: 217–219.

Weaver, S. C., and N. L. Forrester. 2015. Chikungunya: Evolutionary history and recent epidemic spread. Antiviral Res. 120: 32–39.

World Health Organization. 2009. Dengue. Guidelines for diagnosis, treatment, prevention and control. Geneva, Switzerland.

Zanluca, C., V.C.A. de Melo, A.L.P. Mosimann, G.I.V. dos Santos, C.N.D. dos Santos, and K. Luz. 2015. First report of autochthonous transmission of Zika virus in Brazil. Mem. Inst. Oswaldo Cruz. 110: 569–572.

Zhong, D., E. Lo, R. Hu, M. E. Metzger, R. Cummings, M. Bonizzoni, K. K. Fujioka, T. E. Sorvillo, S. Kluh, S. P. Healy, et al. 2013. Genetic analysis of invasive *Aedes albopictus* populations in Los Angeles County, California and its potential public health impact. PLoS ONE 8: e68586.