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Short Communication

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

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Abstract

Aedes (*Stegomyia*) *aegypti* (L.) and *Aedes* (*Stegomyia*) *albopictus* (Skuse) are potential vectors of Zika, dengue, and chikungunya viruses in the United States. A Zika virus outbreak in Florida in the summer of 2016, driven by *Ae. aegypti* and resulting in > 200 locally acquired cases of human illness, underscored the need for up-to-date information on the geographic distribution of *Ae. aegypti* and *Ae. albopictus* in the United States. In early 2016, we conducted a survey and literature review to compile county records for presence of *Ae. aegypti* and *Ae. albopictus* in the United States from 1995 to 2016. Surveillance for these vectors was intensified across the United States during the summer and fall of 2016. At the end of 2016, we therefore conducted a follow-up survey of mosquito control agencies, university researchers, and state and local health departments to document new collection records for *Ae. aegypti* and *Ae. albopictus*. The repeated survey at the end of the year added *Ae. aegypti* collection records from 38 new counties and *Ae. albopictus* collection records from 127 new counties, representing a 21 and 10 percent increase, respectively, in the number of counties with reported presence of these mosquitoes compared with the previous report. Moreover, through our updated survey, 40 and 183 counties, respectively, added additional years of collection records for *Ae. aegypti* and *Ae. albopictus* from 1995 to 2016. Our findings underscore the continued need for systematic surveillance of *Ae. aegypti* and *Ae. albopictus*.

Key words: *Aedes aegypti*, *Aedes albopictus*, surveillance, United States, Zika virus

We previously reported the results of a county-level survey, distributed by the Centers for Disease Control and Prevention (CDC) to vector control professionals, entomologists, and state and local health departments in early 2016, to document the known geographical distribution in the United States of the two primary potential mosquito vectors of Zika, yellow fever, dengue, and chikungunya viruses: *Aedes* (*Stegomyia*) *aegypti* (L.) and *Ae.* (*Stegomyia*) *albopictus* (Skuse) (Hahn et al. 2016). A few months after the survey was concluded, Miami-Dade County in southern Florida experienced a local outbreak of Zika virus transmission driven by *Ae. aegypti* and resulting in >200 locally acquired human cases (Florida State Health Department 2016, Likos et al. 2016). Because intensified surveillance for *Ae. aegypti* and *Ae. albopictus* across the United States during the summer and fall of 2016 was expected to produce new county-level mosquito collection records, we repeated the county-level survey at the end of the year in order to update the previously presented county-level collection record maps for these mosquitoes. Additionally, respondents to the initial CDC survey have had more time to mine their historical mosquito surveillance records since the initial survey ended. Here we provide an update for county collection records for *Ae. aegypti* and *Ae. albopictus* in the United States from January 1995 through December 2016. Efforts are underway to use these data to create climate suitability models for these important mosquito vectors in the continental United States.

Materials and Methods

Selection of Time Period and Criteria for Mosquito Presence Classifications

We included collection records from 1995 to December 2016 (henceforth referred to as 2016) to identify counties that have

reported contemporary collections of *Ae. aegypti* or *Ae. albopictus*. As in Hahn et al. (2016), *Ae. 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. Counties with reported *Ae. aegypti* or *Ae. albopictus* were further classified 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 1995–2016, 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 Collection Records

All records presented in Hahn et al. (2016) were included in the present database, and thus the maps presented here represent the cumulative surveillance data for *Ae. aegypti* and *Ae. albopictus* from 1995 to December 2016. To update collection records for *Ae. aegypti* and *Ae. albopictus* to the end of 2016, we repeated the literature review described in Hahn et al. (2016) for the period from 8 March to 16 December 2016, and we repeated the online survey for county collection records. The link to the online survey was widely disseminated to all respondents from the earlier survey, as well as other stakeholders via the suite of vector control and entomological professional organizations described previously by Hahn et al. (2016). To expand response rates, survey participants were encouraged to invite colleagues to participate in the survey.

The survey tool compiled contact information for the person entering the records, as well as county-level records by year for *Ae. aegypti* and *Ae. albopictus*. If no records were reported for one or both species, respondents had the option to check a box to indicate the absence of collection records. However, given the lack of systematic sampling efforts, absence data are not displayed on our maps. The survey opened 17 November 2016 and responses were requested by 10 December 2016, but the survey tool was available beyond that date. Responses reported here extend through 31 December 2016.

Management of Collection Record Database

We merged the vector presence records from Hahn et al. (2016) with the new records from the follow-up survey. No new county-level collection records for *Ae. aegypti* or *Ae. albopictus* were found via the literature review. We created two datasets, one that contained all the *Ae. aegypti* collection records and one with all the *Ae. albopictus* collection records. These datasets contained the county and year of the mosquito collections. We extracted only one record for each county in a given year for each mosquito species in order to avoid duplicates. For this collection record update, we extracted all records between 1995 and 2016. 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 as been reported by county. Full references for each published record in the final database are included in Supp. Tables 1 and 2 (online only).

Results and Discussion

Number of Counties and States With Reported Occurrence of *Ae. aegypti*

Our county-level collection record update documented *Ae. aegypti* presence in 38 counties that lacked collection records in Hahn et al. (2016), primarily in Texas but also including counties in two states, Illinois and Alabama, previously lacking collection records for *Ae. aegypti* from 1995 to 2016 (Fig. 1, Supp. Table 1 [online only]). The additional counties added to the *Ae. aegypti* database represent a 21 percent increase in number of counties with reported presence of this mosquito. One county, Sedgwick County, KS, was removed from the *Ae. aegypti* database in this update after the survey respondent informed us that this record was due to an entry error. Moreover, additional years of collection records, from those documented previously by Hahn et al. (2016), were reported for 40 counties with previous records of *Ae. aegypti* from 1995 to 2016 (Supp. Table 1 [online only]). These counties were primarily in Texas, Kansas, and southern California.

Adding the new surveillance records to those published previously in Hahn et al. (2016), between 1 January 1995 and 31 December 2016, occurrence of *Ae. aegypti* was reported from 220 counties in 28 states and the District of Columbia (Fig. 1). During the same time period, *Ae. aegypti* was collected in 3 or more years from 101 counties from 16 states and the District of Columbia (Fig. 1). Since 1995, *Ae. aegypti* has been documented from all states in the southern tier of the United States, with the most widespread county-level distributions in southern California, Arizona, Texas, Louisiana, and Florida. County collection records are more sporadic throughout the southeastern United States in Arkansas, Tennessee, and North and South Carolina as well as further north along the Atlantic coast in Maryland, New Jersey, and Washington D.C. There have also been collections made in eastern Kansas and Cook County, IL (Chicago). The geographic distribution of *Ae. aegypti*, which thrives in the subtropics and tropics, is constrained by temperature in the United States (Otero et al. 2006, Eisen and Moore 2013, Brady et al. 2014). In particular, low winter temperatures may limit the survival of overwintering eggs and prevent *Ae. aegypti* from establishing at northern latitudes. However, most regions in the United States experience summer temperatures that are conducive to *Ae. aegypti* development and activity for at least some period of time.

Number of Counties and States With Reported Occurrence of *Ae. albopictus*

Our county-level collection record update documented *Ae. albopictus* records in 127 counties previously lacking collection records for *Ae. albopictus* in Hahn et al. (2016), primarily in Kansas, Texas, Mississippi, and Arkansas (Fig. 2, Supp. Table 2 [online only]). The additional counties added to the *Ae. albopictus* database represent a 10 percent increase in number of counties with reported presence of this mosquito. Moreover, additional years of collection records, from those documented previously by Hahn et al. (2016), were reported for 183 counties with previous records of *Ae. albopictus* from 1995 to 2016 (Supp. Table 2 [online only]). These counties were primarily in Kansas, Texas, Mississippi, Arkansas, and North Carolina.

Adding the new surveillance records to those published previously in Hahn et al. (2016), between 1 January 1995 and December 2016, occurrence of *Ae. albopictus* was reported from 1,368 counties in 40 states and the District of Columbia (Fig. 2). During the same time period, *Ae. albopictus* was collected in 3 or more years from 573 counties from 34 states and the District of Columbia

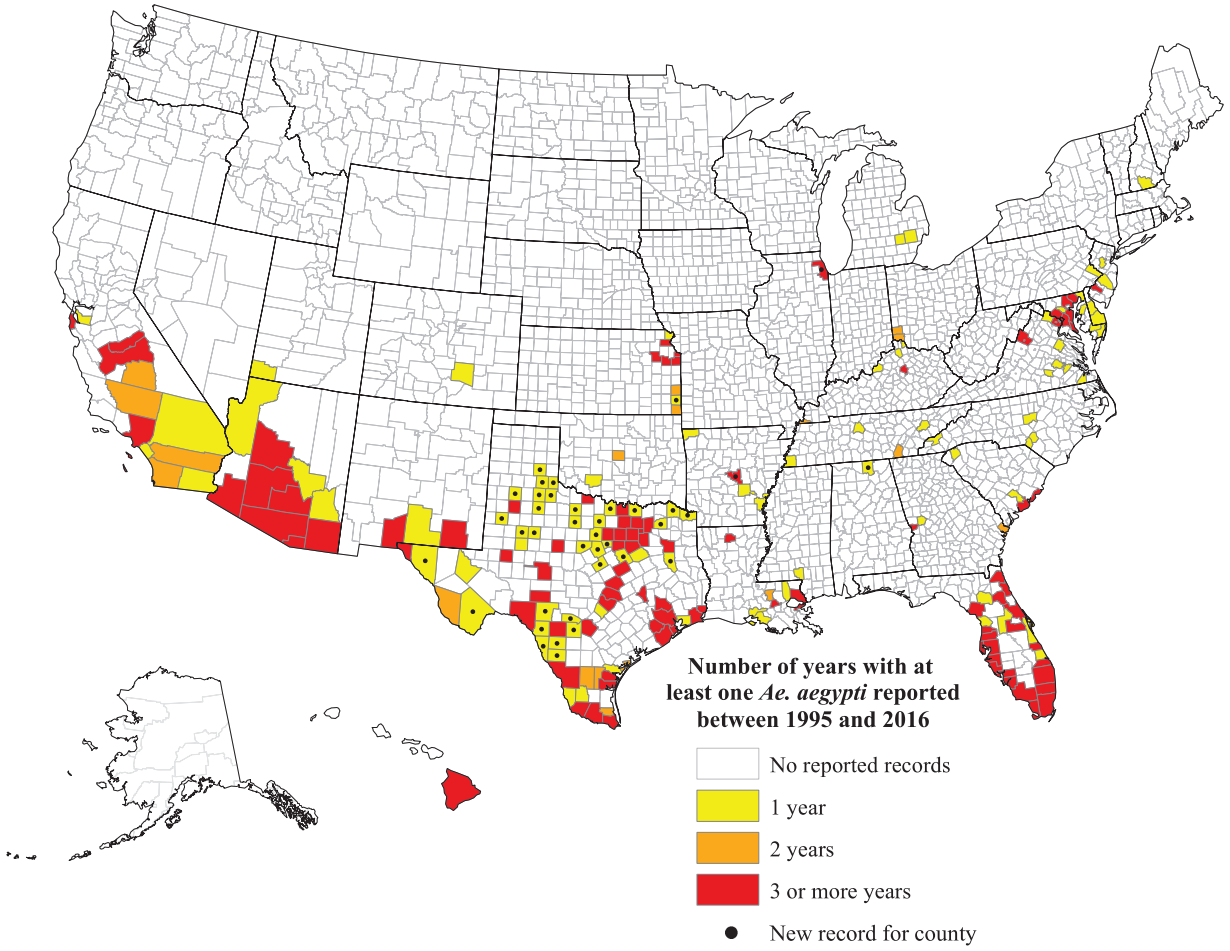

Fig. 1. Maps showing the reported occurrence of *Ae. aegypti* by county between 1 January 1995 and December 2016 in the United States, representing the best knowledge of the current distribution of this mosquito based on collection records. Counties with black dots had new surveillance records in this update. 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 one year within the specified time period, orange indicates those that had two years of presence records within the specified time period, and those shown in red had three or more years of presence records within the specified time period.

(Fig. 2). Since 1995, county-level collections for *Ae. albopictus* are widespread in Southeast, South Central, and Mid-Atlantic states. Established mosquito populations have occurred as far north as northern Indiana, New York, and New Hampshire. Collection records for *Ae. albopictus* are more sporadic in the western United States, mostly occurring in southern California and Arizona. In addition to temperature, the distribution of this mosquito is also limited by water availability (Alto and Juliano 2001). Although the natural conditions in much of the arid southwestern United States may be harmful for *Ae. albopictus*, man-made water sources such as artificial containers and irrigation ditches have allowed the persistence of the mosquito in southern California, Arizona, New Mexico, and western Texas.

Number of Counties With Reported Occurrence of Both *Ae. aegypti* and *Ae. albopictus*

Between 1 January 1995 and December 2016, 177 counties reported occurrence of both *Ae. aegypti* and *Ae. albopictus*. These counties were located mostly in southern California, Arizona, Texas, Florida, and Maryland.

Study Caveats

The county-level collection records presented in this update represent our best knowledge regarding the current distribution of *Ae. aegypti* and *Ae. albopictus* in the United States. However, we caution that these data should be viewed as a compilation of existing records based on convenience sampling rather than systematic surveys. Intensified surveillance for *Ae. aegypti* and *Ae. albopictus* in the summer and fall of 2016, driven by the ongoing Zika virus disease epidemic in the Americas, resulted in these species being documented from numerous new counties. Continued intense surveillance for *Ae. aegypti* and *Ae. albopictus* in the coming years undoubtedly will produce additional county collection records, especially in areas with suitable environmental conditions where surveillance efforts for these mosquitoes have been lacking but now are being initiated as part of new *Ae. aegypti* and *Ae. albopictus* surveillance initiatives funded by local jurisdiction or States, or via the CDC Epidemiology and Laboratory Capacity for Infectious Diseases Program.

To reiterate from Hahn et al. (2016), the collection records in this report represent presence of the mosquito in a county rather than abundance. Moreover, a county-level mosquito presence record does not necessarily mean that the mosquito species in question is present throughout the county, or even that the environment is conducive to its survival and establishment in all parts of the county. Importantly, lack of *Ae. aegypti* or *Ae. albopictus* collection records should not be interpreted as absence of these mosquitoes from a

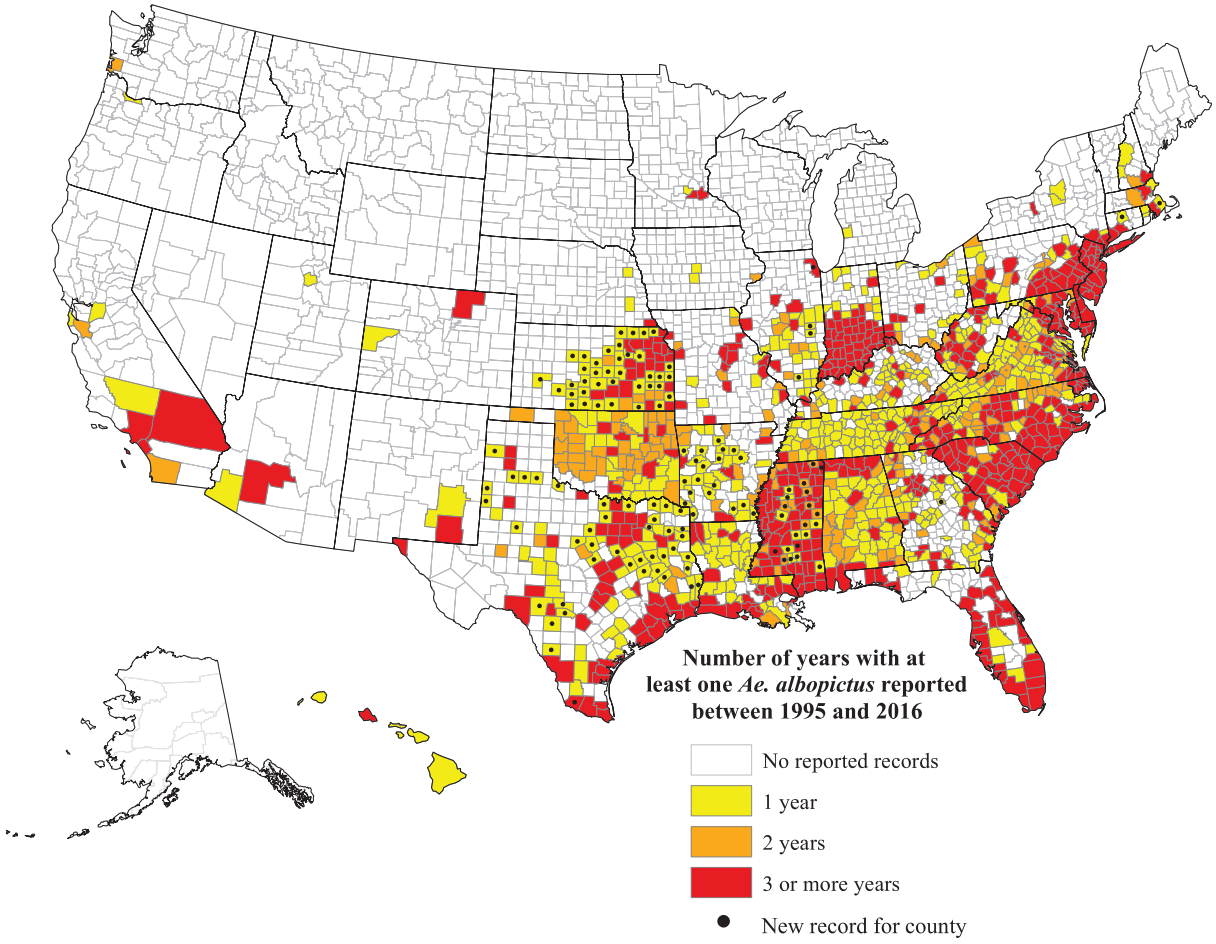

Fig. 2. Maps showing the reported occurrence of *Ae. albopictus* by county between 1 January 1995 and December 2016 in the United States, representing the best knowledge of the current distribution of this mosquito based on collection records. Counties with black dots had new surveillance records in this update. 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 one year within the specified time period, orange indicates those that had two years of presence records within the specified time period, and those shown in red had three or more years of presence records within the specified time period.

county, particularly if the mosquito species has been collected from a nearby county. Conversely, counties with 3 or more years of presence records do not necessarily have established *Ae. aegypti* or *Ae. albopictus* populations. For example, many of the *Ae. albopictus* detections in isolated counties in Utah, Colorado, and Minnesota are the result of repeated introductions of the mosquito in used tire facilities.

Implications for Future Mosquito Surveillance Efforts

Based on our updated county-level distribution map, areas of interest for enhanced surveillance for *Ae. aegypti* include states with established populations such as California, Arizona, New Mexico, Texas, Florida and the other Gulf Coast states, and the Mid-Atlantic states on the northern margin of the distribution. Other areas of interest are urban areas that have repeated introductions of the mosquito such as Chicago, IL. Areas of interest for enhanced surveillance of *Ae. albopictus* include states in the Midwest and eastern United States where there are only 1–2 yr of collection records. Repeated surveillance in these areas is necessary to determine whether these introduced populations have become established. Additional areas for enhanced *Ae. albopictus* surveillance include states such as Missouri, Georgia, and Florida that have fewer surveillance records than expected based on reported mosquito presence in surrounding states. It is essential that surveillance efforts specifically targeting *Ae. aegypti* and *Ae. albopictus* are maintained over time in order to monitor changes in their distribution in the coming years and decades. More consistent surveillance methodology in terms of collection methods used and spatial and temporal collection schemes will allow vector control and public health officials to gain a better understanding of the threat posed by these important arbovirus vectors in the United States. In the meantime, modeling the distribution of these vector species using the available presence data may be an effective tool to refine the areas for enhanced surveillance.

Acknowledgments

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