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SCIENTIFIC NOTE

UPDATED DISTRIBUTION OF *AEDES ALBOPICTUS* IN OKLAHOMA, AND IMPLICATIONS IN ARBOVIRUS TRANSMISSION

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ABSTRACT. A series of statewide surveys were conducted in Oklahoma in the summers between 1991 and 2004 to identify the distribution of *Aedes albopictus*. Adult mosquitoes were identified in 63 counties, bringing the currently known distribution of *Ae. albopictus* in the state to 69 of 77 counties. The widespread presence of *Ae. albopictus* in Oklahoma has important current and future public and veterinary health implications for surveillance and control efforts.

KEY WORDS *Aedes albopictus*, Asian tiger mosquito, invasive species, Oklahoma, distribution

The first established population of the Asian tiger mosquito, *Aedes albopictus* (Skuse), was reported in Harris County (Houston), TX, in 1985 and was subsequently reported in 36 other states (Enserink 2008). By 1997, *Ae. albopictus* was established throughout most of the southeastern USA (Moore and Mitchell 1997). In recent years, *Ae. albopictus* has successfully invaded much of Europe and is continually expanding in range (Benedict et al. 2007, Bockova et al. 2013, Grard et al. 2014).

Aedes albopictus is an important vector of a variety of arboviruses, including La Crosse virus in the USA, dengue virus in South America, the Caribbean, and Africa, and chikungunya virus in Africa and Asia. While occasionally testing positive for West Nile virus (WNV), it is generally not considered to be a significant vector (Bonizzoni et al. 2013). Additionally, *Ae. albopictus* has become a significant vector for *Dirofilaria* sp. in the USA (Wang et al. 2014) as well as in Europe (Bonizzoni et al. 2013). The combination of vector competency and aggressive biting behavior has made *Ae. albopictus* a significant target for mosquito control programs worldwide (Bonizzoni et al. 2013).

On a statewide level, any successful control or elimination strategy begins by documenting the presence of a particular species in a particular locality (country, state, county, urban area) (Janousek et al. 2001, Linthicum et al. 2003, Farajollahi and Nelder 2009). An updated report of the distribution of a particular mosquito species in a given area provides important information for public health, veterinary, and medical professionals as well as the general public. The aim of this report, therefore, is to update the distribution of *Ae. albopictus* in Oklahoma and provide a basis on which to conduct effective mosquito control within the state.

Aedes albopictus was first reported in the state of Oklahoma in 1990 during an Oklahoma State University (OSU)–based survey carried out along the Red River in 5 counties on the Texas border (Wright, unpublished data). It was also reported in Oklahoma County, the site of Oklahoma City, during the same year (McHugh 1991). Further reported in Comanche County in 1991 (McHugh 1992), subsequent surveys in 1992 identified *Ae. albopictus* in 5 additional counties. While several papers have used Oklahoma data which were submitted by one of the authors (KB) to ArboNET, a national arboviral surveillance database managed by the Centers for Disease Control and Prevention (CDC) (Hynes 2012, Wang et al. 2014), the actual process for obtaining those data has not yet been published.

Survey work to detect *Ae. albopictus* between 1992 and 2004 mainly took place during 2 time periods: 1) 1997–2000 in a directed effort by OSU to identify *Ae. albopictus* distribution in Oklahoma, and 2) 2003–04 during WNV surveillance efforts. The 2003–04 mosquito collection and testing projects were supported by the Oklahoma State Department of Health (OSDH) through grant funding provided for WNV surveillance by the CDC.

During the summers of 1997–2000, *Ae. albopictus* was identified in counties in eastern and central Oklahoma where it had not yet been reported (Fig. 1). Ovitraps using ¾-in. (~19-mm) tongue depressors (Elnimed Inc., West Chester, OH) were used in order to increase convenience for volunteer participation. City workers and extension personnel who were certified for insecticide application through the Oklahoma Department of Agriculture, Food and Forestry in specific counties were recruited by OSU Extension personnel. After agreeing to participate, ovitraps were sent to volunteers and

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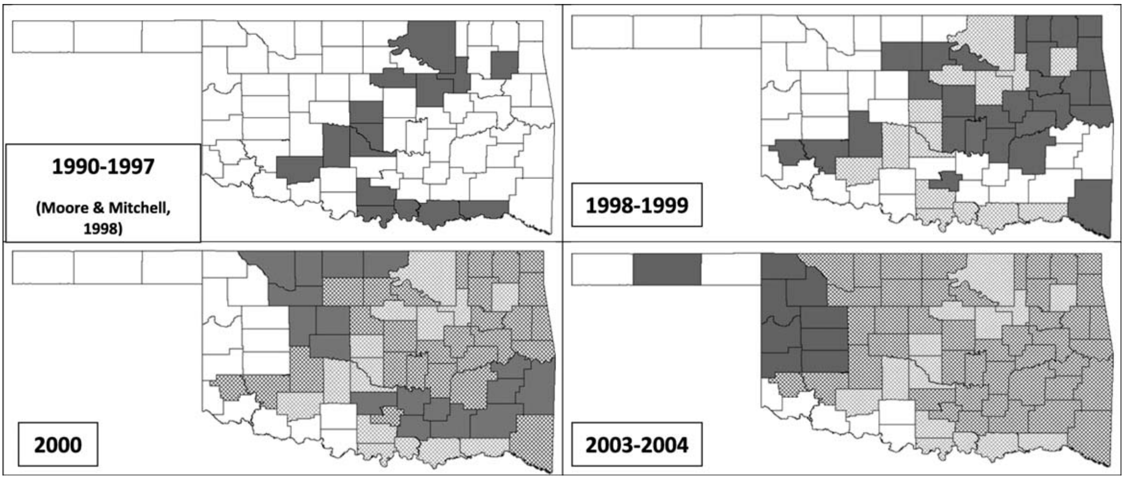

Fig. 1. Distribution of *Aedes albopictus* in Oklahoma and record of sampling efforts between 1990 and 2004 (light cross-hatch = original counties reported; dark-solid = counties sampled during that time period; dark-hatch = positive counties from previous time periods; white = not yet sampled).

specific oviposition sites were chosen in their domestic area or within recreational parks in urban areas or nearby state parks. Biweekly, the volunteers would send the oviposition sticks to OSU via mail or they would be picked up by an OSU vehicle and delivered to the Department of Entomology and Plant Pathology. By the summer of 2000, surveying was mainly orchestrated by OSU personnel in city parks or state park/recreational areas using 2 or 3 ovitraps per site and collecting egg strips once weekly.

On arrival at the OSU facilities, the oviposition sticks were examined immediately for mosquito eggs at 10× under a microscope. Egg-positive sticks were held for 1 wk to allow egg development, after which they were hatched in tap water (aerated for 24 h prior to use). Larvae were allowed to mature and pupate, at which time they were transferred into enclosed paper cartons until adult emergence. Three days postemergence, adult mosquitoes were frozen. Adult mosquitoes were identified to genus and species, and the sex and number recorded for each location. Specimens from each county were pinned and labeled as voucher specimens to be placed in the K.C. Emerson museum housed in the Department of Entomology and Plant Pathology in the Noble Research Center at OSU.

Between 1997 and 2000, *Ae. albopictus* was identified in all 48 Oklahoma counties that were surveyed (Fig. 1). The surveyed area covered all counties east of Oklahoma City as well as most of the central region of the state. Of a total of 2,859 of mosquitoes reared and identified, 1,754 (61.4%) were *Ae. albopictus*, with the rest either *Ae. triseriatus* Say or *Ae. hendersoni* Cockerell.

Between 2003 and 2004, the OSDH contracted with the OSU Department of Entomology and Plant Pathology to organize and conduct surveillance for WNV in geographically diverse areas in the state. During these 2 summers, the *Ae. albopictus* survey was expanded into 10 new counties in the western part of the state. Collections consisted of: 1) oviposition traps previously described (Beaver, Harper, Ellis, Dewey, Roger Mills, and Custer counties), or 2) adult sampling using CDC gravid traps baited with fermented grass water or CDC miniature light traps with CO_2 and octenol attractants (Texas, Woodward, Beckham, and Washita counties). City, county, and extension personnel identified local mosquito problem areas and acquired permission to set traps on private property. Eggs were removed from the ovitraps biweekly and sent to OSU. Eggs were hatched in the laboratory and reared to the adult stage for identification.

Between the summers of 2003 and 2004, *Ae. albopictus* was identified in 9 of the 10 counties that were sampled (Fig. 1). The eggs recovered in Beaver County were not viable on returning to the laboratory. At the present time, only 8 counties remain to be surveyed for the possible presence of *Ae. albopictus* (Cimarron, Beaver, Harmon, Jackson, Tillman, Cotton, Jefferson, and Stephens) (Fig. 1). Judging from current distribution patterns, it is highly likely that *Ae. albopictus* will be present in every county in Oklahoma.

The distribution of *Ae. albopictus* in Oklahoma is important from an ecological as well as a public health and veterinary health perspective. As one of the most ecologically diverse states in the USA (Web Atlas of Oklahoma 2005), the presence of *Ae. albopictus* in all 11 eco-zones demonstrates the ability of this mosquito species to invade diverse habitats (Bonizzoni et al. 2013) and provides a unique environment in which to study invasion biology. Recent studies have highlighted the ability of *Ae. albopictus* to utilize components of the invasive eastern red cedar (*Juniperus virginiana* L.), which occurs throughout the Great Plains of the USA (Reiskind and Zarrabi 2011, O'Brien and Reiskind 2013).

An aggressive daytime biter, *Ae. albopictus* has been reported as a vector for La Crosse virus in Texas (Lambert et al. 2010), dengue virus in South America, the Caribbean, and Africa, and chikungunya in Africa and Asia (Bonizzoni et al. 2013). While 8 pools of *Ae. albopictus* tested positive for WNV in Oklahoma between 2003 and 2007 (Bradley, unpublished data), it is generally not considered to be a significant vector for WNV (Bonizzoni et al. 2013). Of veterinary significance, *Ae. albopictus* has become the main vector of *Dirofilaria immitis* (Leidy) in urban centers in central Oklahoma (Paras et al. 2014), possibly displacing *Ae. trivatattus* (Coquillet) as the urban vector of canine heartworm in the state (Afolabi et al. 1988). The recent reports of local dengue transmission in Texas (Murray et al. 2013) and Florida (Trout et al. 2010) and chikungunya in the Caribbean (Weaver 2014) by *Ae. albopictus* have important implications for future mosquito control and prevention efforts within the south-central USA.

Most of the WNV surveillance and control efforts in the USA in recent years have used versions of the gravid trap in urban communities (Chung et al. 2013, Godsey et al. 2013). With the possibility of a rapid movement of chikungunya virus into the USA, vectored in part by indigenous *Ae. albopictus* populations, control programs will need to incorporate additional surveillance tools in their programs because gravid traps target mainly *Culex* mosquitoes. The currently recommended trap for *Ae. albopictus* is the BG-Sentinel® trap (Biogents AG, Regensburg, Germany), which has been shown to be highly effective in the USA (Farajollahi et al. 2009, Obenauer et al. 2010) and in the Caribbean (Barrera et al. 2013) and South America (De Ázara et al. 2013). This added surveillance need will involve budgetary considerations as small city/county control units must consider how to expand surveillance protocols with limited budgets. The possibility to enhance the effectiveness of BG-Sentinel traps using CO_2 to collect *Culex* spp. as well as *Ae. albopictus* could be a viable option for future mosquito control and surveillance budgets (De Ázara et al. 2013).

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