Changes in *Aedes albopictus* (Diptera: Culicidae) Populations in New Jersey and Implications for Arbovirus Transmission

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ABSTRACT The Asian tiger mosquito *Aedes albopictus* (Skuse) was first detected in New Jersey in 1995 during mosquito surveillance operations in Monmouth County. We tracked statewide changes in populations of the Asian tiger mosquito and its association with West Nile virus from 2003 to 2007. *Ae. albopictus* population abundance has increased in New Jersey since 2003, primarily along the urban corridor between New York City and Philadelphia, and they are now expanding their range further into suburban and rural areas of the state. *Ae. albopictus* has invaded all counties of New Jersey except for two northwest rural counties (Sussex and Warren). West Nile virus was detected in *Ae. albopictus* throughout several foci in New Jersey during the study, underscoring the public health significance of this mosquito.

KEY WORDS Asian tiger mosquito, distribution, geographical information system, invasion biology, West Nile virus

The Asian tiger mosquito *Aedes albopictus* (Skuse) (Diptera: Culicidae) was first established in North America in Houston, TX, during 1985 and has since spread to 36 additional states (Sprenger and Wuithiranyagool 1986, Enserink 2008). The species was first detected in New Jersey from Monmouth County in 1995 (Crans et al. 1996). In a mere 20 yr, continental U.S. populations of *Ae. albopictus* have become associated with several arboviruses such as Cache Valley, eastern equine encephalitis, Jamestown Canyon, La Crosse, and West Nile (Moore and Mitchell 1997, Gerhardt et al. 2001, Turell et al. 2005). If introduced into the United States, exotic arboviruses such as chikungunya (CHIKV), dengue, and yellow fever could be effectively vectored by *Ae. albopictus.* Understanding the current expanding distribution, abundance, and vector status of this mosquito in the northeast is critical for developing novel surveillance and control measures. Our objective was to track the population changes of *Ae. albopictus* and its association with West Nile virus (WNV) using geo-referenced data collected during vector surveillance operations throughout New Jersey.

Materials and Methods

Our study was conducted during five transmission seasons from early summer (May) through fall (October) 2003–2007 throughout New Jersey. Mosquito control personnel collected specimens from 21 counties as part of a statewide vector surveillance program. Mosquitoes were collected by a variety of vector surveillance traps (primarily gravid and CO_2-baited traps), identified to species, and tested for WN-viral RNA by TaqMan RT-polymerase chain reaction (PCR) assays (Farajollahi et al. 2005). Trapping locations were not static and varied in response to WNV activity, as documented through WNV-positive birds, equines, humans, and historic areas of virus foci. Considering there is a lack of standard surveillance methods for *Ae. albopictus*, pool numbers were used as a proxy for population changes, especially considering that this was a passive surveillance program for *Ae. albopictus.* Correlations (Pearson coefficients) were calculated between the yearly mosquito surveillance efforts (i.e., the total number of traps set, the total number of all mosquito species collected and submitted for WNV testing, and the total number of sites trapped) and yearly *Ae. albopictus* populations (i.e., the total number of *Ae. albopictus* pools submitted for WNV testing) (Zar 1999).

Results

Expansion of *Ae. albopictus* in New Jersey was determined to be restricted to areas of higher human population densities, particularly in metropolitan and suburban New York and Philadelphia; other areas of increased population numbers were located near Toms River, Atlantic City, and Trenton (Fig. 1). Little or no range expansion was detected into rural areas of New Jersey (i.e., northwestern and central pinelands

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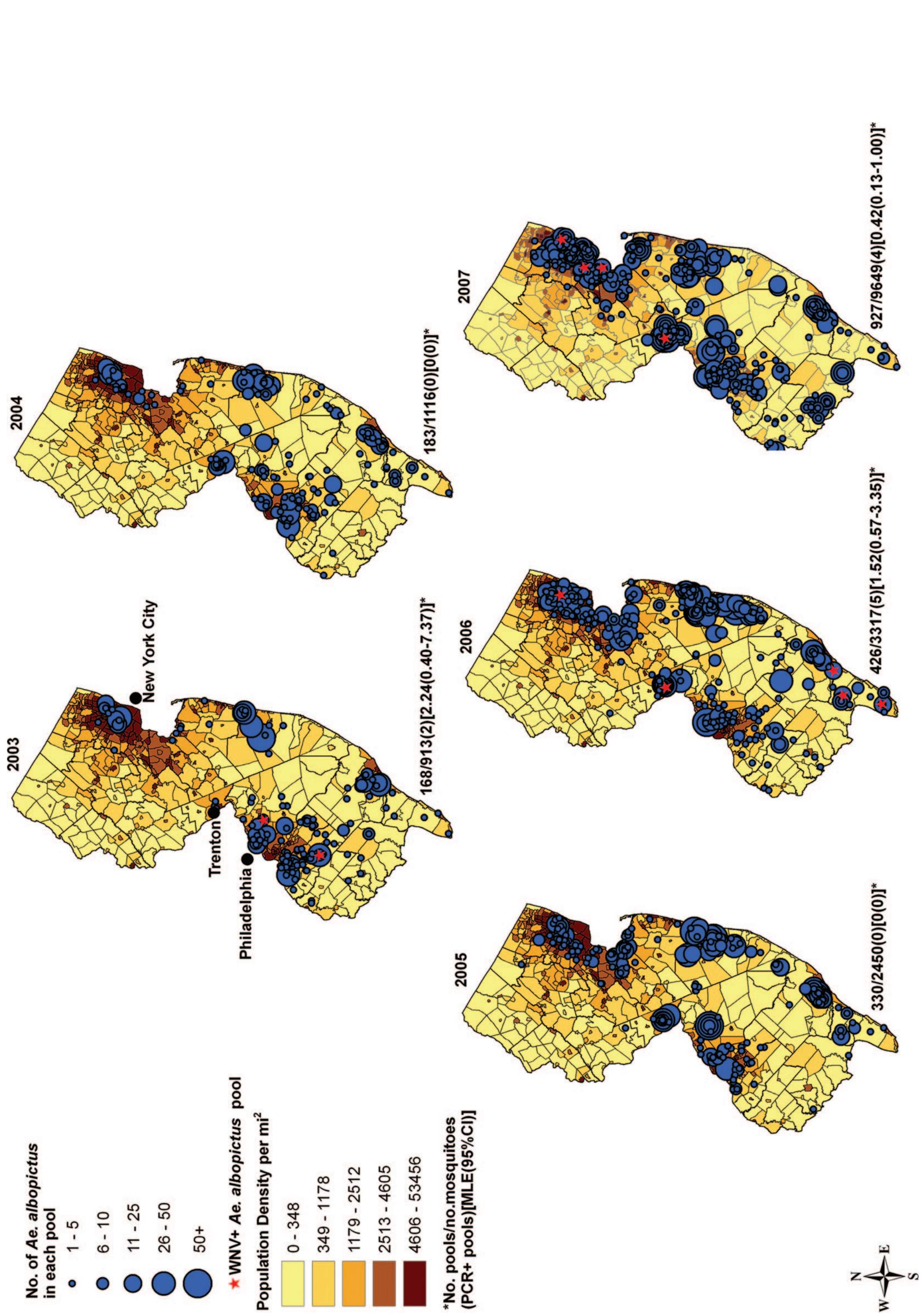

Fig. 1. *Aedes albopictus* pools collected in New Jersey (2003–2007) indicating WNV-positive pools and human population density. WNV infection rates in *Ae. albopictus* calculated as means per 1,000 mosquitoes with 95% confidence intervals using a bias-corrected maximum likelihood.

regions; Fig. 1). A dramatic increase in service-request calls, from Mercer County residents in response to *Ae. albopictus* biting activity (confirmed by adult and larval collections), was noted during our study period. In 2003, no service requests were related to *Ae. albopictus;* in other years, service requests were as follows: 2004, 9 service requests; 2005, 16 service requests; 2006, 51 service requests; 2007, 57 service requests. The initial infestation of *Ae. albopictus* in Mercer County was confined to central Trenton in 2003, but expansion has occurred into suburban and rural areas of the county (Fig. 2).

The total number of traps set for all species (including *Ae. albopictus*) for 2003 was 8,884; in other years, traps set were as follows: 2004, 6,822 traps; 2005, 5,897 traps; 2006, 5,339 traps; 2007, 7,306 traps. The total number of all mosquito species collected and submitted for WNV testing for 2003 was 174,198; for 2004 was 132,559; for 2005 was 126,969; for 2006 was 122,521; and for 2007 was 128,963. The total number of sites trapped throughout New Jersey was as follows: 2003, 1,605; 2004, 1,171; 2005, 1,199; 2006, 1,129; 2007, 1,257.

WNV infection rates in *Ae. albopictus* were calculated as the mean per 1,000 mosquitoes tested with 95% confidence intervals using a bias-corrected maximum likelihood method. WNV infection rates in *Ae. albopictus* were the highest in 2003 (2.2 [0.4–7.4]), followed by 2006 (1.5 [0.6–3.5]), 2007 (0.4 [0.1–1.0]), and no infection rates in 2004 and 2005 (Figs. 1 and 2). WNV-positive pools were primarily detected in areas with relatively higher populations of *Ae. albopictus.* There were no significant correlations between the total number of traps set and the total number of *Ae. albopictus* pools ($r = -0.12$. $P = 0.85$), the total number of all mosquito species collected, the total number of *Ae. albopictus* pools ($r = -0.44$. $P = 0.46$), and the total number of sites trapped and the total number of *Ae. albopictus* pools ($r = -0.26$. $P = 0.67$). Lack of correlations indicates *Ae. albopictus* population increases were independent of sampling efforts.

Discussion

Since its initial detection in New Jersey in 1995, the Asian tiger mosquito has invaded all counties except for those in northwest rural areas (Sussex and Warren Counties). Slower spread to northwest and south central regions of the state may indicate a lack of preferred oviposition sites (i.e., human-derived artificial containers) in these areas and the simultaneous invasion of these habitats by another invasive species, *Aedes japonicus* (Theobald), or perhaps competition from other container-inhabiting species [e.g., *Aedes triseriatus* (Say) and *Culex pipiens* L.]. In certain areas such as Trenton, Mercer County, *Ae. albopictus* has spread beyond the inner city to surrounding suburban and rural areas, indicating that the spread of *Ae. albopictus* to rural areas has not been as rapid as the spread to urban areas. The spread of the Asian tiger mosquito to rural areas is occurring, and the two uninfested counties are likely to become infested in the near future.

WNV has been detected from *Ae. albopictus;* however, the role of *Ae. albopictus* in WNV transmission to humans is unclear. Although primarily mammophillic, *Ae. albopictus* will opportunistically feed on birds and may acquire the pathogen from West Nile viremic birds (Savage et al. 1993). *Ae. albopictus* is a highly efficient laboratory vector of WNV (Sardelis et al. 2002) and is potentially an important bridge vector of WNV (Turell et al. 2005). The relatively high population numbers of *Ae. albopictus,* coupled with WNV-positive pools, in New Jersey urban centers suggests that this mosquito is a potential threat to public health.

The expansion of *Ae. albopictus* populations into areas of high human population density generate potential foci for the transmission of exotic arboviruses, especially in areas with high concentrations of immigrants and travelers returning from endemic regions. Chikungunya virus is a mosquito-transmitted arbovirus that infects humans and causes polyarthralgia (Hochedez et al. 2008). The mosquitoes responsible for CHIKV transmission are *Aedes aegypti* L. and *Ae. albopictus.* Thirty-seven cases of imported CHIKV were reported from the northeast United States (one from New Jersey) from travelers returning from India and La Réunion in 2006; seven of the eight travelers (with measured CHIKV titers) had titers $>10^4$ PFU/ml; high titers of this scale or magnitude are known to infect mosquitoes (Turell et al. 1992, Lanciotti et al. 2007). *Ae. albopictus* populations from the United States are efficient vectors of CHIKV virus under laboratory conditions (Turell et al. 1992). New Jersey residents may be at risk of acquiring CHIKV, especially when viremic persons are in close contact with vectors and susceptible individuals (i.e., vector transmits CHIKV from an infected individual to proximate, susceptible individuals in a situation of high human population density). The threat of *Ae. albopictus* transmission of an exotic virus has already been realized in Italy with CHIKV (Beltrame et al. 2007). For 2006 and 2007, people born in India make up the highest percentage (10.4% or an estimated 185,000 individuals) of foreign-born persons living in New Jersey (State of New Jersey Department of Labor and Workforce Development 2008), providing an example of the threat from people returning from CHIKV-endemic areas and initiating local transmission in New Jersey.

We have documented population changes of *Ae. albopictus* populations in New Jersey with increases in range and relative abundance; these trends could become common across other developed regions in the United States where climatic and environmental conditions are suitable for colonization. We have also documented associations between WNV and *Ae. albopictus* from field collections, further underlining the public health importance of this invasive mosquito. Ensuing global warming and subsequent milder winters in New Jersey has potentially led to a higher probability of *Ae. albopictus* eggs to overwinter successfully, given that increases in winter temperatures increase survival of overwintering eggs (Hanson and

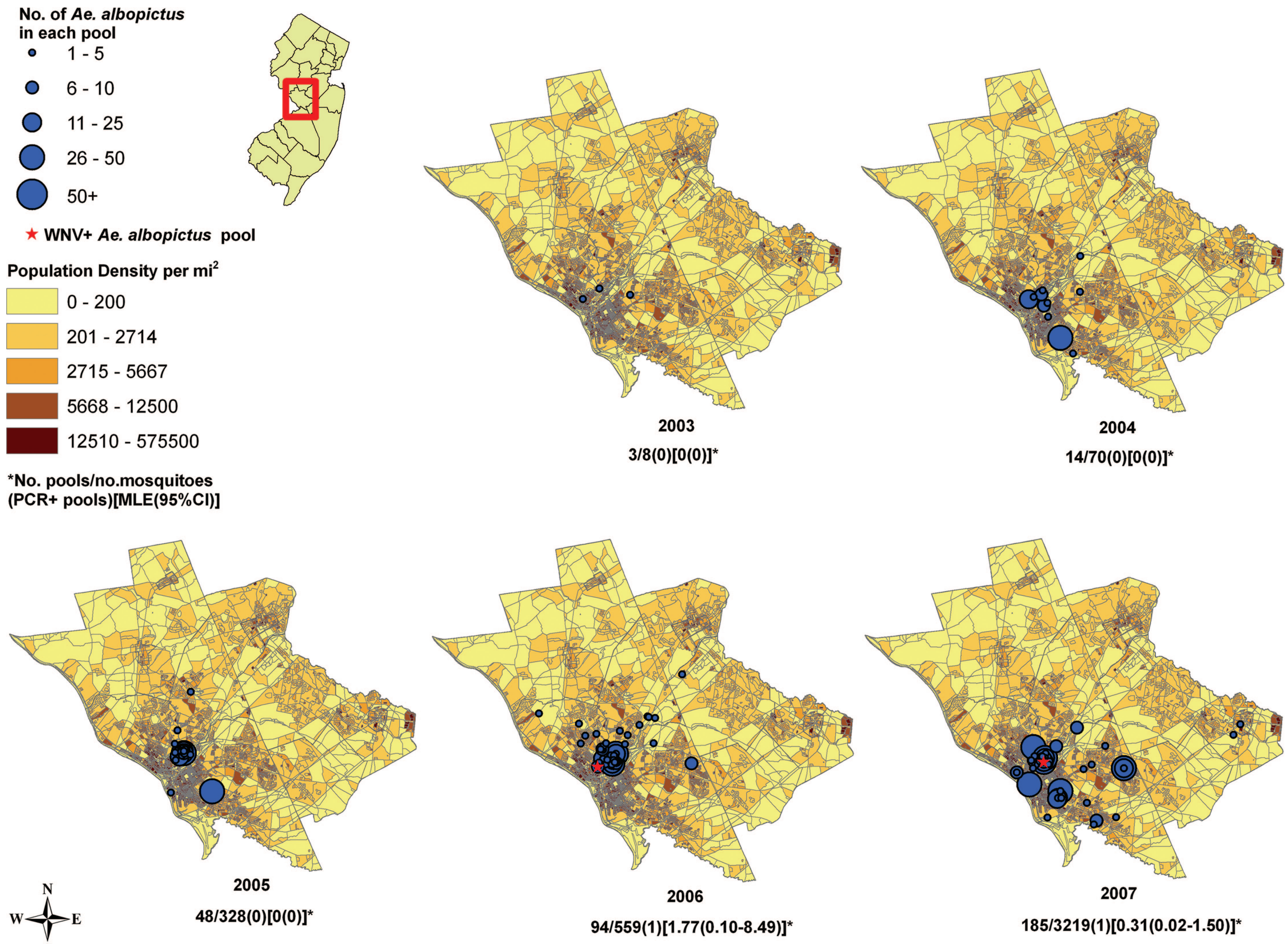

Fig. 2. *Aedes albopictus* pools collected in Mercer County, NJ (2003–2007), indicating WNV-positive pools and human population density. WNV infection rates in *Ae. albopictus* calculated as means per 1,000 mosquitoes with 95% confidence intervals using a bias-corrected maximum likelihood.

Craig 1995). Average winter temperatures in New Jersey since 1984 (≈1.0°C) are above the historical average of 0.1°C (1896–2007), with six winters reaching average temperatures ≥2.2°C (New Jersey Weather and Climate Network 2008). Contributing to population changes of *Ae. albopictus* is the ubiquitous nature of artificial container habitats within these densely populated regions and the difficulty in either removing refuse or treating artificial containers with conventional biological or chemical insecticides. Mosquito control in New Jersey has traditionally focused on rural mosquito species such as the inland floodwater mosquito *Aedes vexans* (Meigen) and the Eastern salt marsh mosquito *Aedes sollicitans* (Walker). In contradistinction, *Ae. albopictus* is an urban and suburban problem, pleading for a paradigm shift in mosquito control. Expanded surveillance for *Ae. albopictus* and subsequent control are urgently needed within the urban landscape where the potential for introduction of an exotic arbovirus is high.

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