Evaluating risk for Zika, chikungunya virus transmission across eastern states

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Mosquito-borne disease occurs when specific combinations of conditions maximize virus-to-mosquito and mosquito-to-human contact rates. The recent spread of mosquito-transmitted viruses and associated disease to the Americas demonstrates the need for a data-driven evaluation of risk in temperate population centers. **Carrie Manore** of the Laboratory's Theoretical Biology and Biophysics group and a team developed a mathematical model informed by field data to assess the conditions likely to facilitate local transmission of the Zika and chikungunya arboviruses from an infected traveler to the tiger mosquito and then to other people in cities in the eastern United States. The journal *PLOS Neglected Tropical Diseases* published their findings.

Significance of the work

The ability to manage mosquito population growth and associated arboviral transmission to humans requires early recognition of conditions that facilitate high mosquito population density and human biting behavior. When these conditions are favorable, transmission following the arrival of an infectious traveler can progress rapidly. Zika and chikungunya arboviruses are transmitted by *Aedes* mosquitoes, including the Asian tiger mosquito (*Ae. albopictus*). These mosquitoes are abundant in cities located in temperate climates. While disease risk is lower in temperate regions where viral amplification cannot build across years, there is significant potential for localized disease outbreaks in urban populations under certain conditions. Public health officials need validated assessments of how likely these viruses will be locally transmitted. Because 80% of Zika infections are asymptomatic, time to detection of an outbreak and response could be longer than for other diseases.

The team created a mathematical model that captures the epidemiology and includes field data to assess the conditions likely to facilitate local transmission of virus from an infected traveler to the Asian tiger mosquito and then to other people in U.S. cities. The researchers examined conditions of variable human densities and seasonality. This work demonstrates how a conditional series of non-average but realistic events could result in local arbovirus transmission and outbreaks of human disease, even in temperate cities. This study highlights the need for high-resolution spatial data on tiger mosquito density, biting behavior, and seasonality to better understand, predict, and manage arboviral transmission risk in temperate cities.

Scientists and public health officials involved with arbovirus transmission have had limited ability to make credible predictions, in part based on incomplete information about conditions that permit an outbreak and the likelihood those conditions will arise. The new model provides quantitative assessments of the probability of an outbreak and the potential numbers of human victims when key parameter values can be specified. Guided by published data on virus and mosquito vital rates, the model indicates that outbreaks can plausibly occur in major cities in the eastern United States, with hundreds of potential victims in localized areas, under conditions that are not atypical. The model suggests that outbreaks are more likely in urban areas with higher human and mosquito population densities, in years with longer growing seasons, when infected travelers arrive early in the growing season, and when tiger mosquitos have fewer non-human hosts that result in wasted bites. These conditions are most likely met in urban areas where social, structural, and environmental conditions facilitate human-mosquito contact and potentially limit early detection and mitigation of local transmission.

Achievements

The team evaluated how the duration of active mosquito season following the arrival of an infectious traveler and propensity for biting diverse vertebrate species - where every non-human bite slows the transmission process - influence outbreak potential for different urban densities. The researchers performed the calculations for New York, Philadelphia, Atlanta and Washington, DC.

Their model demonstrated that up to 50% of Zika-infected travelers returning to the U.S. could initiate local transmission in temperate cities if they are infectious and are exposed to high mosquito densities early in the mosquito season. Moreover, 10% of the introductions could result in 100 or more people infected. Despite the propensity for *the mosquitos* to bite non-human vertebrates, the study revealed that local virus transmission and human outbreaks might occur when the mosquitos feed from humans even just 40% of the time. Inclusion of human behavioral changes and mitigations were not incorporated into the models and would likely reduce predicted number of infections. The researchers conclude the urban wildlife ecology, weather conditions, and human behavior all could strongly influence the probability of new outbreaks in major U.S. cities.

The research team

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Reference, “Defining the Risk of Zika and Chikungunya Virus Transmission in Human Population Centers of the Eastern United States,” *PLOS Neglected Tropical Diseases* (2017); doi: 10.1371/journal.pntd.0005255.

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Shown below is the distribution of the Asian tiger mosquito (orange dots) and major urban areas (blue triangles).