Researchers study potential for emergence of mosquito-borne disease

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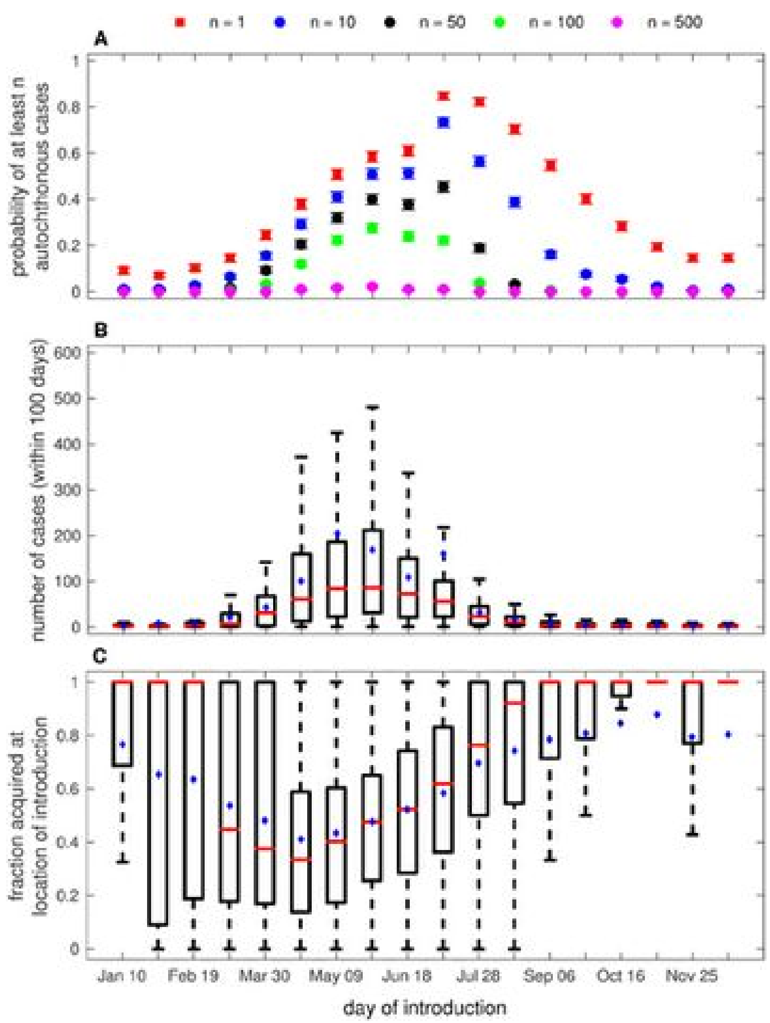

The probability that at least n autochthonous cases occurred following a single introduction on the date given on the horizontal axis (error bars are the probability of autochthonous transmission ± the binomial standard deviation). (B) The total number of dengue cases that occurred within 100 days of a single introduction on the date listed along the horizontal axis. (C) The fraction of total cases that occurred in the location of introduction. All other parameter values are as given in Table 1. In the box plots in (B) and (C), red lines indicate the median, blue dots indicate the mean, and the box represents the interquartile range. Whiskers indicate the interquartile range multiplied by 1.5. Credit: University of New Mexico

With Zika virus raising concerns around the United States about the spread of mosquito-borne diseases, the transmission of these viruses has become paramount in terms of how, when and where they are spread. Researchers at The University of New Mexico are using mathematics to try and learn more about the potential for emergence of mosquito-borne disease in metropolitan areas in the United States.

Working under the mentorship of University of New Mexico Associate Professor Helen Wearing, Postdoctoral Fellow Michael Robert in the Departments of Biology, and Mathematics and Statistics developed a mathematical model to study introduction and spread of mosquito-borne diseases in U.S. urbanized areas. The researchers highlighted the utility of this model by investigating the case of dengue fever in the Miami Urbanized Area (Miami UA), a region in which imported cases of dengue have been reported frequently in the past six years.

Dengue is a mosquito-borne viral infection that typically causes flu-like symptoms but can develop into a potentially lethal complication called dengue hemorrhagic fever. The global incidence of dengue has grown dramatically in recent decades, and the World Health Organization estimates that about half of the world's population is at risk of dengue today. Dengue is spread by the same mosquito species that transmits Zika virus and chikungunya: Aedes aegypti.

Robert and his colleagues used the model to study the role of timing and location of introduction in determining whether introductions of dengue in the Miami UA will lead to local transmission and outbreaks in the context of seasonal fluctuations in the mosquito population and human movement patterns determined by daily commuting behavior.

"While this model is not yet capable of making exact predictions about how many cases can be expected after an introduction of dengue, it can help us to better understand what times of the year are most at risk for local transmission and outbreaks due to changes in the size of the mosquito population," Robert said. "It also helps us to understand how human movement could contribute to the spread of local transmission throughout the region."

"This study could potentially assist in understanding why large outbreaks of dengue in southern Florida have been rare despite numerous imported cases," Robert said. In their model, the researchers found that outbreaks following introductions in fall were smaller than those following introductions in the late-spring and summer. Most of the imported cases of dengue that occurred in 2010-2015 were reported in late summer and early fall when the mosquito population is lower relative to mid-summer. Importations in late-spring and early-summer have been less common.

The researchers also utilized the model to help understand the potential impact of low reporting rates on detection and perceived outbreak size. "Because symptoms of dengue are typically mild, people who acquire the infection may not see a doctor, and thus those cases go unreported," Robert said. "For example, in the 2009-2010 dengue outbreak in Key West, it is estimated that only about 5-10% of all cases were reported. The model allows us to estimate the total number of cases that could have occurred when reporting rates are low, which helps us to better understand how likely it is that an outbreak can be detected with low reporting rates.""We showed that the time of year in which an imported case of dengue arrives within the Miami UA influences both the probability of local transmission and the ultimate number of locally acquired cases," Robert said. "Although according to our model, introductions in June and July led to the highest probability of local transmission, introductions in May often led to the greatest number of cases. This result emphasizes the need for proactive mosquito control measures that begin in late-spring and early-summer even if the mosquito population and the number of dengue cases observed at the time are low."

Additionally, the researchers tested the robustness of the model to changes in parameters that are poorly understood for the Miami UA, namely the transmission rate and the ratio of mosquitoes to humans in the region. "One great utility of the model is that it can help us to understand what role the many unknown variables could play in transmission and spread of dengue in the region," Robert said. "For instance, it is difficult to estimate the number of mosquitoes that transmits the virus in the region, which determines the ratio of mosquitoes to humans. It is also difficult to estimate how often mosquitoes and humans come into contact, which is important for accurately estimating the transmission rate. Without understanding these values, it is almost impossible to predict the risk of transmission and the number of cases that could occur with any degree of certainty."

This model could be adapted to study other potential threats such as chikungunya and Zika virus to the Miami UA and other metropolitan areas in the U.S. such as New Orleans, Houston, and New York City. Because dengue, chikungunya, and Zika virus are all spread by the same mosquito species, areas where any one of the three viruses has been transmitted are potentially suitable for transmission of the other two.

Chikungunya became established in the western hemisphere in 2014 and imported cases were detected in nearly all U.S. States. Over 400 imported cases were detected in Florida in 2014, and the majority of those were in southern Florida. Zika virus was first detected in the Western Hemisphere in 2015 and is rapidly spreading throughout Central and South America. As of September 28 2016, the CDC has reported 3566 travel-related cases of Zika virus in the United States, 783 of which were reported in Florida. According the Florida Department of Health, 133 locally acquired cases of Zika virus have been reported in Florida since July 2016, 132 of which have occurred in the Miami Urbanized Area.

Robert and Wearing conducted this study in collaboration with Noah Silva, a graduate student working under the direction of Wearing in the Department of Biology, Rebecca Christofferson and Christopher Mores at Louisiana State University, and Chalmers Vasquez at Miami-Dade Mosquito Control Division. Robert with continue to work with Drs. Wearing and Christofferson who were recently awarded an NIH grant to examine the role of temperature variation in mediating the transmission of chikungunya and Zika viruses.

Provided by University of New Mexico

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