Vector Dynamics and Disease Transmission across an Urban Gradient

Key words: urban ecology, vector-borne disease, condition-specific competition

Vector-borne diseases have increased in urban environments in recent decades.[1] Incidence of vector-borne disease is often unevenly distributed across urban landscapes, which are themselves comprised of a diversity of landscape features that can modify thermal microclimates. Because mosquitoes are small ectotherms, their growth, survival, and reproduction are all sensitive to fine-scale variation in environmental temperature.[2] Further, the abundance and persistence of vector habitat and potential hosts can vary significantly across populations of different socioeconomic statuses.[3] Finally, urbanization is altering the composition of mosquito communities, with urban environments becoming dominated by invasive, anthropophilic species, such as *Aedes albopictus*.[4] Understanding how vector populations, and resulting pathogen dynamics, change across urban environments is critical for informing public health efforts and requires an assessment of the relative effects of both ecological and sociological factors, and their interactions, on vector-borne disease transmission.[5]

In the Southeastern US, *Aedes albopictus* is an established species of tropical origin, while *Aedes japonicus,* a more temperate species, has only recently begun invading from its point of introduction in New York.[6,7] Both species are competent vectors of human disease, including dengue and Chikungunya, [8,9] which has recently emerged in the US, and persist in urban environments.[10] Although studies have found that *A. albopictus* larvae outcompete *A. japonicus* in a controlled setting,[9,10] species coexistence, not competitive exclusion, is found in the field.[11,12] This is likely because experimental settings do not account for realistic microclimate heterogeneity, thereby disregarding **condition-specific competition**[13,14] resulting from temperature-dependent interactions at the microclimate scale.

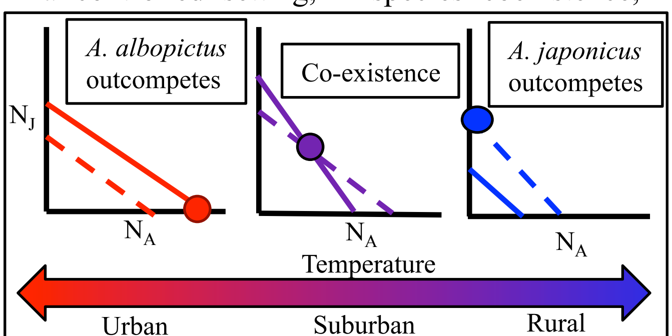

Figure 1. Lotka-Volterra models of predicted condition-specific competition between *A. albopictus* (N_A;solid) and *A. japonicus* (N_J; dashed) across temperature and urban gradients, leading to different outcomes.

The role of temperature in mosquito-borne disease transmission is well studied[15]; however, the relationship between competition and transmission potential is less so. Higher larval competition could lead to lower adult fitness, and larval competition has been shown to increase viral dissemination of Sindbis virus in *A. aegypti*, but not in *A. albopictus*,[16] suggesting that the response differs across species. Competition also affects mosquito life-history traits such as reproduction, development time, and survival,[17] all of which influence vectorial capacity. In order to predict how *A. japonicus* invasion will influence disease dynamics in urban zones, **we must understand how vector competition and its effect on disease transmission change across an urban gradient.**

In spite of the recognition that mosquitoes are especially sensitive to microclimate, no study has integrated climactic variation into their exploration of competitive interactions between mosquito invaders. Additionally, very few studies extrapolate their community ecology findings to inform vector-borne disease transmission models. My proposed plan integrates laboratory work, field experiments, and mathematical modeling and mapping to answer three questions:

AIM 1: Do mosquitoes experience condition-specific competition across a temperature gradient? *H_1: Mosquitos experience condition-specific competition over a temperature range,* *with lower temperatures decreasing the effect of A. albopictus on A. japonicus, allowing for coexistence (Fig. 1).*

A. albopictus and *A. japonicus* larvae will be reared in the lab in species ratios of 0:1, 0:2, 1:1, 2:0, and 1:0 in natural (i.e. leaf litter) environments. These treatments will be replicated across the range of climactic variation seen in the field, which we collected in a pilot study this fall. I will place emerged adults in cages at identical temperatures to collect life table data such as age-specific survival and reproduction, biting rates, and intrinsic population growth rates. These data will be used to construct growth curves and Lotka-Volterra models of competitive outcomes.

AIM 2: Does the heterogeneity of an urban gradient create the conditions necessary for condition-specific competition? *H_2: The heterogeneity of urban environments allows for condition-specific competition between mosquito species, with similar results as in H_1.*

To capture heterogeneity in the urban environment, I will run competition experiments as outlined in Aim 1 across three different land-use types (urban, suburban, and rural), defined by the proportion of impervious surface and canopy cover, in Athens, GA. This experiment will be replicated three times for a total of 9 land-use sites and 45 experimental samples. Adults collected will be reared in cages *in situ,* separated by day of emergence to measure adult mortality. Temperature and humidity will be measured in the larval and adult environment of each sample to collect finer scale climate data. Concurrently, I will survey sites in all three land-use types for mosquito larval habitat abundance, size, and quality. Adult mosquito populations will be surveyed with BG Sentinel traps to compare mosquito community composition across sites. These results will be used to validate the earlier models based on laboratory conditions.

AIM 3: How does condition-specific competition affect disease transmission across an urban gradient? *H_3: Condition-specific competition will lead to differential disease risk, and models including this will be more accurate than prior models that do not include competition.*

The data on mosquito life history traits collected in AIM 1 and 2 can be combined with estimates from the literature on pathogen development (Chikungunya and dengue) to infer how transmission potential might vary across urban landscapes and under condition-specific competition. Integrating variation in transmission potential with social data such as socio-economic level and healthcare availability, which are predictors of human exposure in related systems (e.g. West Nile virus[18]), I will create models and maps of disease risk. Incorporating social data into ecological disease models is still relatively new, and is something I am well suited to do, because of my interdisciplinary background.

Broader Impact: Urbanization's impact is not limited to mosquitoes, and my work examining condition-specific competition can be applied to other ectotherms. I plan to collaborate with local vector control agencies, and generate reports that can be used to inform public health efforts. Additionally, I will create a citizen science project to monitor perceived mosquito intensities, which will be compared to predicted disease risk based on my models. The University of Georgia has an active infectious disease REU program through which I will mentor undergraduates to help train the next generation of disease ecologists.

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