



Original Contribution

Aedes Mosquito Infestation in Socioeconomically Contrasting Neighborhoods of Panama City

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Abstract: The global expansion and proliferation of *Aedes aegypti* and *Aedes albopictus* represents a growing public health threat due to their capacity to transmit a variety of arboviruses to humans, including dengue, chikungunya, and Zika. Particularly important in urban regions, where these species have evolved to breed in man-made containers and feed nearly exclusively on human hosts, the threat of vector-borne disease has risen in recent decades due to the growth of cities, progression of climate change, and increase in globalization. While the dynamics of *Aedes* populations in urban settings have been well studied in relation to ecological features of the landscape, relatively less is known about the relationship between neighborhood socioeconomic status and *Aedes* infestation. Here, we compare infestation levels of both *A. aegypti* and *A. albopictus* in four socioeconomically contrasting neighborhoods of urban Panama City, Panama. Our results indicate that infestation levels for both *Aedes* species vary between neighborhoods of contrasting socioeconomic status, being higher in neighborhoods having lower percentage of residents with bachelor degrees and lower monthly household income. Additionally, we find that proximity between socioeconomically contrasting neighborhoods can predict infestation levels by species, with *A. aegypti* increasing and *A. albopictus* decreasing with proximity between neighborhoods. These findings hold key implications for the control and prevention of dengue, chikungunya, and Zika in Panama, a region with ongoing arbovirus outbreaks and high economic inequity.

Keywords: Mosquito, Vector-borne disease, Social determinants of health, Entomology

INTRODUCTION

Recently, geographically restricted forest-transmitted mosquito viruses such as Asian chikungunya (CHIKV) and African Zika (ZIKV) have become a growing health con-

cern among novel urban areas worldwide (Li et al. 2014). The successful invasion and establishment of these viral pathogens into new geographic areas is due to the increased presence of *Aedes aegypti* or *Aedes albopictus* mosquitoes (Gratz 2004; Singer 2017). *A. aegypti* and *A. albopictus* thrive in urban settings because they can fulfill important ecological needs living alongside humans, including water for immature stage development, blood for female reproduction and shelter that protects larvae and adults against

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harsh climatic conditions. Indeed, the spatial distribution and localized relative presence of *Aedes* mosquitoes is often used as a direct predictor of where disease outbreaks are likely to occur in human populations; hence, it is important to identify the drivers of *Aedes* population dynamics in urban areas (Andreadis et al. 2004; Mwangangi et al. 2012).

Drivers of *Aedes* occurrence in urban landscapes are multifaceted in nature and often time involve a complex interplay among biological, ecological, socioeconomic, and political factors. For example, the presence of *Aedes aegypti* has been linked to the use of flower vases for religious practices, water storage in lower containers, lack of mosquito preventive measures plus mistaken knowledge and perception about disease, education level, and socioeconomic stratum of human populations (Spiegel et al. 2007; Quintero et al. 2009; Little et al. 2017). Naturally, *Aedes* populations are driven by the particular distribution of eggs laid; females select egg-laying sites that reduce exposure to predators and competitors (Blaustein and Kotler 1993; Kiflawi et al. 2003), allow greater access to food (Blaustein and Kotler 1993; Reiskind et al. 2009), in response to chemosensory cues from conspecifics (Afify and Galizia 2015), or to the size and color of the container (Torrissi and Hoback 2013). Therefore, understanding egg-laying decisions and their implications on adult populations may provide additional insight into the regulators of mosquito populations and assist in predicting how populations will respond to control measures (Nylin 2001). The quality, purpose, and density of container habitats are likely important factors of urban mosquito community ecology as well. Past studies have shown that managed containers (e.g., plant pots, bird baths) usually have less accumulation of detritus than unmanaged containers (Murrell and Juliano 2008) and that container purpose varies across a socioeconomic gradient (Dowling et al. 2013b). Changes in man-made container characteristics, water temperature, and pH can also considerably influence the composition of the available resources and timing of development into adults (Bayoh and Lindsay 2004; Sattler et al. 2005). Nevertheless, the scope and scale of the effect of habitat characteristics on *Aedes* infestation in urbanized settings is still largely unknown.

Variation in socioeconomic status and a history of spatial segregation of resources have had a profound effect on ecosystem services, ecological complexity, and sustainable revitalization efforts in urban landscapes (Grimm et al. 2008; Pickett et al. 2011). Preliminary evidence of *Aedes* presence varying across a socioeconomic gradient was

found in row-home neighborhoods of Baltimore and Washington D.C., with the availability of larval breeding habitat and individual species presence directly related to the median income of the neighborhood (Dowling et al. 2013b; LaDeau et al. 2015; Little et al. 2017). Additionally, several studies in the USA have examined the effects of variation in urban form and socioeconomics on the distribution of *Culex* mosquitoes, especially in the early 2000s following the first reported cases of West Nile Virus (WNV). These works showed a direct relationship between the presence of *Culex* mosquitoes and landscape features more prevalent in neighborhoods of lower socioeconomic status, such as unmaintained storm drains (Calhoun et al. 2007; Ruiz et al. 2007; Chaves et al. 2009; Estep et al. 2010). Overall though, prior assessments have taken place in locations where *Aedes*-borne arbovirus outbreaks are minimal or nonexistent. The only study using a metropolitan area where dengue (DENG), CHIKV, and ZIKV outbreaks are common, in Bangladesh, found that socioeconomic characteristics of a neighborhood cannot predict *Aedes* infestation rates (Dhar-Chowdhury et al. 2016). Thus, in order to contribute to a small but growing body of literature that contains competing conclusions in limited geographic territories, we conducted our study in Central America, where wealth disparity is widespread and epidemics of DENG, CHIKV, and ZIKV are common.

In 2002, *A. albopictus* was introduced for the first time into Panama and has since proliferated mostly across rural regions of the country (Miller and Loaiza 2015). In urban Panama City though, resident *A. aegypti* can be found solely or alongside *A. albopictus*. At the macroecological scale, the current distribution of both *Aedes* species seems to be governed by a combination of multiple invasion events into the Isthmus of Panama, human-assisted dispersal through the primary road system, and biological competition between rural and urban environments (Miller and Loaiza 2015; Eskildsen et al. 2018). Despite recent efforts to better understand the ecology of *Aedes* mosquitoes in Panama, we know very little as to how contrasting socioeconomic conditions of human communities affect *Aedes* species occurrence. The objective of our study was to assess the levels of *Aedes* infestation, defined here as percentage of positive traps, in four starkly socioeconomically contrasting neighborhoods of urban Panama City, Panama. Based on the limited previous studies demonstrating an association between mosquito presence and neighborhood socioeconomic conditions (Dowling et al. 2013b; LaDeau et al. 2013), we hypothesized that the infestation of *A. aegypti*

and *A. albopictus* would be higher in neighborhoods of lower relative socioeconomic status (SES) as compared to others with relatively higher SES.

METHODS

Study Site

With a metropolitan population of 1.6 million people, Panama City is the second most populous city in Central America, behind Guatemala City. According to a 2016 United Nations report, Latin America has the highest income inequality of any region on Earth (Barcena 2016), with Panama having the second most unequally distributed wealth in the region, with a Gini coefficient (standard statistical measure of income inequality) of 0.50. Panama City specifically has a considerable divide between high- and low-income communities, ranking in the top 20 of cities on Earth with the most unequally distributed wealth. Approximately 48% of the country lives below the poverty line while the wealthiest 20% own 50% of the nation’s overall wealth (Goñi et al. 2011; The World Bank 2015). This has led to vastly different neighborhood structures and environments depending on the SES of the residents, including highly wealthy communities situated in close proximity to slums. Dengue fever has existed in Panama since the 1970s, but chikungunya virus was brought to the country in 2014, followed by Zika virus in 2015. Since 2015, all three *Aedes*-borne viruses can be found in the metropolitan Panama City, yet no studies have sought to address the differential risk that may be associated with the city’s stark socioeconomic inequality. The concurrent circulation of three major arboviruses, increasing human populations, and marked wealth inequality make Panama

City a strategic location to test socioecological theories of *Aedes* infestation.

We determined mosquito sampling areas by creating a socioeconomic index of each county “*Corregimiento*” or neighborhood, similar in size to a US census tract in an urban region. In order to create the index, we chose two key metrics that have been used previously to describe local socioeconomic conditions for health disparity research (Krishnan 2010; Lalloue et al. 2013): (1) percentage of residents with bachelor degrees or higher and (2) monthly household income. While these values are indeed correlated, thus giving us the option to use one rather than both, the relationship is not a perfect 1:1. Each metric contributes to a more comprehensive and nuanced picture of a neighborhood; therefore, we chose to include both in the index. We used the normalized, then averaged values of these attributes for each *Corregimiento* from the National Institute of Statistics and Census (2010) to attain a percentile ranking of SES for all *Corregimientos* in metropolitan Panama City. We then selected four focal neighborhoods, two in the 95th percentile (Costa Del Este and Punta Pacifica), representing high-SES neighborhoods and two in fifth percentile (Boca La Caja and Altos De Las Torres), representing low-SES neighborhoods (Table 1). The primary goal was to select one high-SES neighborhood and one low-SES neighborhood in close proximity, and then the same combination as before, but located further apart (Fig. 1). This would allow us to identify between-group effects (e.g., the effect of proximity) as well as within-group effects (e.g., the effect of socioeconomic variation). We also attempted to ensure that human population density, housing density, and Normalized Difference Vegetation Index (NDVI), a satellite-gathered measure of greenness, were consistent across all focal neighborhoods. This was conducted by comparing *Corregimiento*

Table 1. Sample neighborhoods with the Shannon land cover diversity index, patch density, and edge density, and primary land use type

	Socioeconomic status	Proximity	Patch density	Edge density	Shannon Diversity Index	Primary land use type
Costa del Este	High	Low	11,403.32	3076.53	1.0703	Single homes
Punta Pacifica	High	High	5973.28	1606.651	0.7397	High rises
Altos de las Torres	Low	Low	11,840.72	2869.52	0.8901	Single homes
Boca la Caja	Low	High	6075.74	1694.17	0.5842	Slum/informal settlements

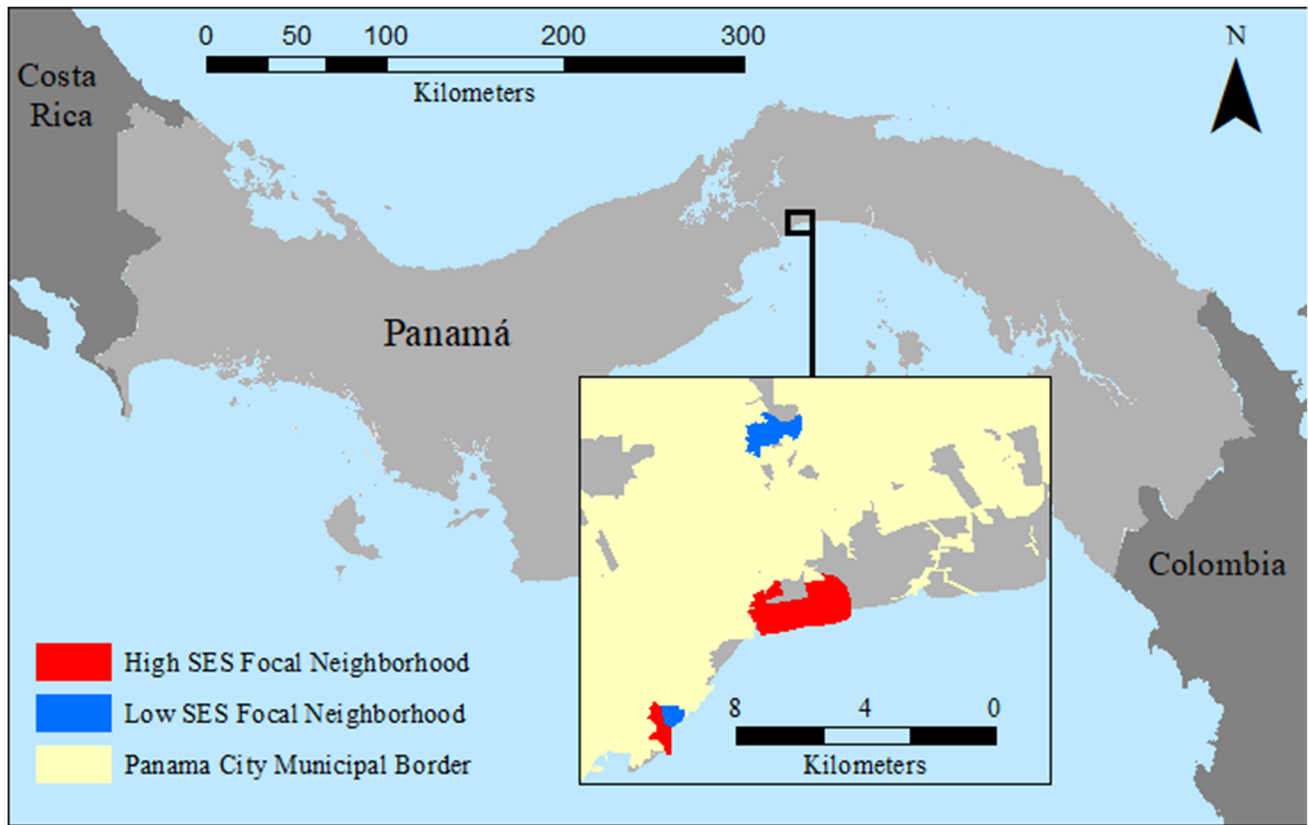


Figure 1. Location of focal neighborhoods and Panama City relative to the Republic of Panama and the surrounding region.

census data as well as NDVI (Landsat 8, 30 m resolution, November 2016 capture) collected, processed, and downloaded from the Smithsonian Tropical Research Institute GIS OpenData Portal (<http://stridata-si.opendata.arcgis.com/>). Corregimiento data and NDVI were consistent across neighborhoods.

Mosquito Surveys

We selected the trap sites within Costa Del Este, Punta Pacifica, Boca La Caja, and Altos De Las Torres by generating 100-m (m) grids for each neighborhood and then placed traps as close to each vertex in the grid as possible. Each neighborhood has a total of 27 traps, 17 Gravid *Aedes* Traps (GATs) and ten Oviposition Traps (OTs: “Appendix”). Both of these traps consist of water-filled plastic buckets meant to attract females who have previously consumed a blood meal and are seeking a container to lay their eggs (Figs. 2, 3; Ritchie et al. 2014a).

As with all insect surveys, the goal to prevent the double sampling of a single population remains paramount. While flight distance can be as much as 500 m

(Honório et al. 2003), several studies on *Aedes* hot-spot size have found that lifetime flight distances rarely exceed 30 m, with the probability of finding spatially correlated populations decreasing exponentially to under 0.50 at distances as small as 15 m (Chansang and Kittayapong 2007; Schaffrick et al. 2013; LaCon et al. 2014). Thus, a 100-m minimum distance between traps is sufficient to ensure independence of trap samples, especially given the heterogeneity of the urban landscape at the 100-m scale. Traps were checked once a week from October 11, 2017 to December 16, 2017. This period represents second half of the rainy season in Panama, and it is characterized by high precipitation and consequently high mosquito densities. Adults from the GATs were taken to the laboratory to be identified and counted (Farajollahi and Price 2013), while eggs and larvae from the OTs were allowed to develop into adults before taxonomic identification. Data from both traps was recorded as presence-absence of *A. aegypti* and *A. albopictus* or both.



Figure 2. Photograph of oviposition trap setup in the field.

Data Analysis

We used a generalized linear model (GLM) and cross-validation to determine and confirm the relationship between

the binary presence or absence of *A. albopictus* or *A. aegypti* and the SES of the neighborhood, input as high or low. We also generated land cover variables based on the heterogeneity of the landscape around each trap site to include in the model as predictors. Specifically, we classified aerial orthophotos (sub-1-m resolution) obtained from the National Authority of Land Management (<http://www.anati.gob.pa/>) using the software eCognition (Trimble 2018) and analyzed land cover composition using the software FRAGSTATS (McGarigal et al. 2012). We calculated the Shannon land cover diversity index, patch density, and edge density within a 30-m radius of each trapping site, chosen based on the previous research into the average radius of urban *Aedes* hot spots (LaCon et al. 2014). These land cover metrics can have ecological implications for mosquito habitat requirements, as certain species prefer certain assemblages of different land cover types or amounts. For example, shade, which can be provided by either vegetation or buildings, provides refuge from midday heat for both *A. albopictus* and *A. aegypti* (Vezzani and Albicocco 2009). Additionally, some species thrive in areas where land cover diversity is high (Vanwambeke et al. 2007, 2011), allowing for a variety of ecological functions including host-seeking, oviposition, and day-time resting. Thus, our dependent variable was represented by the binary



Figure 3. Photograph of gravid *Aedes* trap (GAT) setup in the field.

Table 2. Percent of traps positive for *A. aegypti* and *A. albopictus* in each of the four survey neighborhoods in Panama City, Panama

Neighborhood	<i>A. aegypti</i> (%)	<i>A. albopictus</i> (%)	Coexistence (%)
Costa del Este	34.72	32.86	13.75
Punta Pacifica	27.12	10.17	6.67
Altos de Las Torres	30.26	55.26	20.00
Boca la Caja	59.32	20.34	8.33

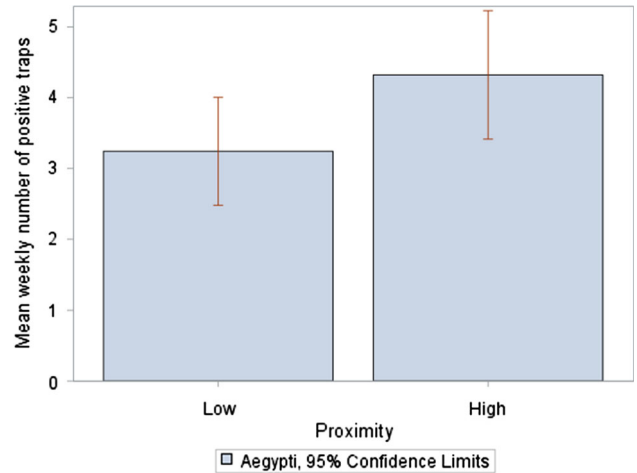
Table 3. Results of the generalized linear model (GLM) predicting the presence of *A. aegypti* and *A. albopictus* across high- and low-SES and high- and low-proximity neighborhoods in Panama City, Panama

	Coefficient	Standard error	<i>P</i>
<i>A. aegypti</i>			
SES	− 0.365	0.161	0.024
Proximity	0.339	0.157	0.031
Constant	− 2.055	0.387	0.000
<i>A. albopictus</i>			
SES	− 0.547	0.184	0.003
Proximity	− 1.054	0.233	0.000
Constant	− 0.626	0.438	0.153

presence of *A. albopictus* or *A. aegypti* caught each week at each trap, while independent variables included the SES of the neighborhood, the proximity of the contrasting neighborhood (high or low), plus the three land cover metrics (e.g., Shannon land cover diversity index, patch density, and edge density) at the 30-m-radius scale. We ran and validated the model using the Crossfold module in Stata (Daniels 2012).

RESULTS AND DISCUSSION

A total of 37% of the total 267 OT checks were positive for *A. aegypti*, while a total of 31% were positive for *A. albopictus*, though the percentages varied across the neighborhoods for both species (Table 2). The GATs were found to be highly biased against *A. albopictus*, with only four (> 1%) of the total 528 GAT checks found to be positive for this species, compared to 22% being positive for *A. aegypti*. Because of the limited sample size and clear

**Figure 4.** Effect of neighborhood proximity on the number of OTs positive for *A. aegypti* in urban Panama City.

species bias found with the GATs, only the data from the OTs were included in the GLM analysis.

For *A. aegypti*, the presence was significantly greater in the low-SES neighborhoods as well as in the high-proximity neighborhoods. For *A. albopictus*, the presence was significantly greater in the low-SES neighborhoods as well, but it was higher in the more distance neighborhoods (Table 3; Figs. 4, 5, 6, 7). Neither species was affected individually by the Shannon land cover diversity index, patch density, and edge density, yet coexistence of both species versus the presence of one was positively related to log patch density (coefficient = 0.00007, *P* = 0.00).

Our illustration of higher relative presence for both *A. aegypti* and *A. albopictus* in low-SES neighborhoods is significant for several reasons. First, it supports a growing body of evidence linking *A. albopictus* infestation to neighborhood SES (Unlu et al. 2011; Dowling et al. 2013a; LaDeau et al. 2013), as well as a similar pattern for *A. aegypti* (Joshi et al. 2006; Ferreira and Chiaravalloti Neto 2007; Spiegel et al. 2007; Quintero et al. 2009). While they are closely related species, *A. aegypti* is considered to be

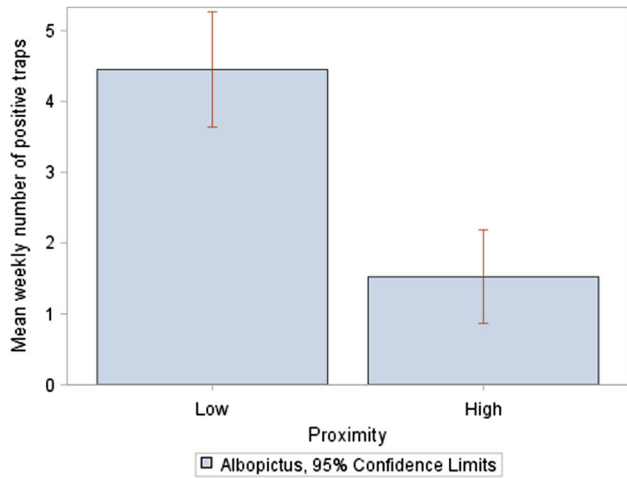


Figure 5. Effect of neighborhood proximity on the number of OTs positive for *A. albopictus* in urban Panama City.

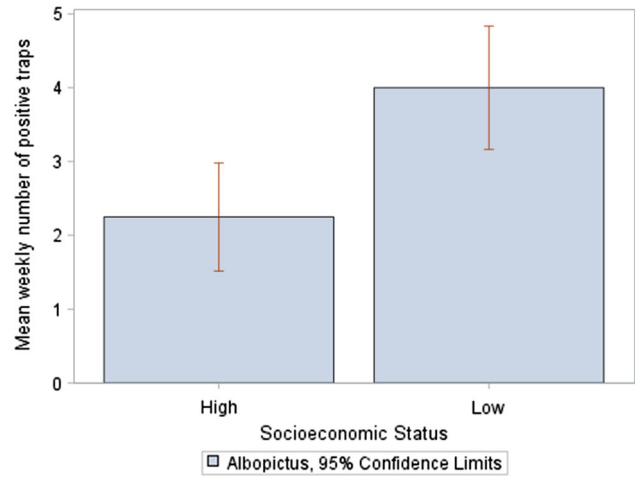


Figure 7. Effect of neighborhood SES on the number of OTs positive for *A. albopictus* in urban Panama City.

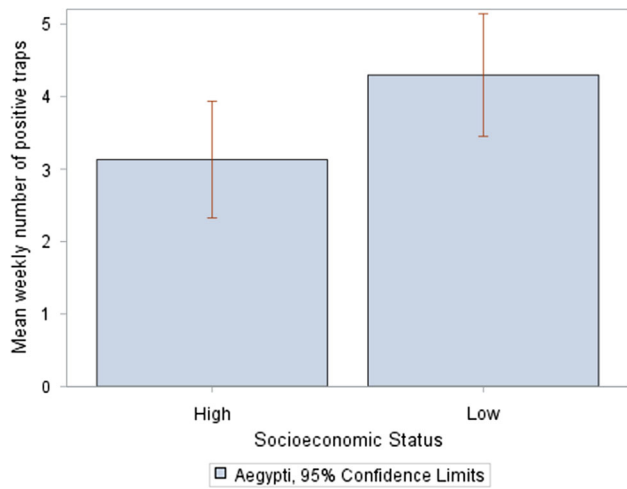


Figure 6. Effect of neighborhood SES on the number of OTs positive for *A. aegypti* in urban Panama City.

more reliant on artificial containers in highly urbanized areas for breeding than *A. albopictus* (Bonizzoni et al. 2013), which is more opportunistic and can breed in natural habitat in suburban areas as well. Thus, the significant occurrence of *A. aegypti* in lower SES neighborhoods may indicate a higher relative abundance of unmaintained artificial containers that accumulate water as has been suggested in previous studies (Dowling et al. 2013b). To be clear, it is not the actual difference in SES that directly predicts vector presence, but rather the landscape characteristics that SES can be a proxy or indicator for which are direct drivers of vector distribution. While more unmaintained standing water may be the simplest explanation, it is not the only possible reason for why vector infestation differs between socioeconomically distinct neighborhoods.

One likely alternative could be the unequal distribution of either personal preventative measures neighborhood scale vector control campaigns (Padmanabha et al. 2010). Additionally, a previous study conducted in these exact four neighborhoods found that residents in the low-SES neighborhoods are less knowledgeable of the causes, symptoms, and prevention methods of *Aedes*-borne diseases (Whiteman et al. 2018b). Effective efforts to eradicate vector-borne disease can often be skewed toward higher SES neighborhoods, or entrenched in local administrative inefficiencies or political biases (Reisen et al. 2008; Tedesco et al. 2010). This has important implications for health disparities. One potential limitation of our methods that may affect the interpretation of the results was our inability to assess existing breeding habitat at each trap site. First, because of how small, cryptic, and ephemeral a water-filled container can be and still host larvae, our ability to accurately quantify available oviposit sites at each trap site was considerably limited. This was further complicated by the fact that features such as trash heaps, ditches/streams, and barbed-wire fencing often physically prevented us from checking all areas around each trap. Overall, our study indicates that residents in lower SES neighborhoods may be at a greater risk of exposure to vectors, and thus potential viruses they transmit. As such, we suggest that public health officials proportionally scale their vector control programs based on the effect that SES can have on vector presence.

The effect of proximity between high and low-SES neighborhoods on the presence of *A. aegypti* and *A. albopictus* is less clear based on our findings and appears to be species-specific. It may also be a result of only assessing a

limited number of neighborhoods. Rather than increasing the number of neighborhoods and decreasing the number of traps per neighborhood, due to resource limitations, we chose to maximize the number of traps in few but starkly contrasting neighborhoods. Thus, as in any similarly designed study, we are limited in our ability to extrapolate results to the greater region. However, we welcome future studies that seek to improve on this work by involving more locations in their assessment. Still, for the high-proximity neighborhoods, the higher relative presence of *A. aegypti* over *A. albopictus* indicates that despite the high-SES neighborhood directly bordering the low-SES neighborhood, there may be minimal adult dispersion of *A. albopictus*. Likewise, despite existing far beyond the flight range of an *A. albopictus* mosquito (Honório et al. 2003), there was higher relative presence of the species in the low-proximity neighborhoods. While this may again be a relic of a small sample size, the regional transfer of used tires, a common artificial breeding habitat and mechanism for global vector dispersal (Reiter and Sprenger 1987), may render neighborhood proximity a relatively unimportant factor, if for example tire shipments are more frequently occurring between low-proximity neighborhoods (Bennett et al., Submitted to Parasites and Vectors journal). This may imply that in highly connected urban areas, with sophisticated transportation networks, the proximity between neighborhoods may play less of a role in vector dispersal than the connectivity of neighborhoods. For instance, distant neighborhoods with high-frequency traffic may incur a greater chance of vector dispersal than close neighborhoods with low-frequency traffic, though field tests are certainly needed to confirm this hypothesis. Including additional neighborhoods in assessments as well as a spatial focus on the used tire trade within a singular urban region may be worthwhile pursuits of future investigation as well.

Another key result was the relative failure of the GATs to provide a useful sample dataset. The GAT has been successfully tested and favorably compared to other gravid traps for both *A. aegypti* and *A. albopictus* (Whiteman et al. 2018a; Farajollahi et al. 2009; Ritchie et al. 2014b; Eiras et al. 2014), yet in our study it presented considerable problems. Future studies and surveillance efforts should be aware of the potential for a major sampling bias against *A. albopictus*. We are unsure of why the traps failed to attract *A. albopictus* in areas where OTs, which are constructed in a similar design, confirmed their presence. However, this indicates the value in utilizing multiple types of traps in a

surveillance study, decreasing the likelihood of an effort wasted due to equipment malfunction.

CONCLUSION

Mosquito ecology and pathogen transmission risk are inherently coupled natural–human systems, where both vector behavior and risk of human exposure to pathogen are intrinsically linked to physical characteristics of the landscape, in addition to political, social and economic forces (Guthman 2008; Tedesco et al. 2010; Medeiros-Sousa et al. 2015). In order to effectively reduce the risk of public health crises among urban communities, it is imperative that integrative mosquito surveillance efforts and pathogen prevention campaigns examine the effects anthropic elements have on vector population dynamics. However, while previous studies have provided valuable insights into mosquito community ecology in natural environments, few have addressed the complexity of interacting socioeconomic and ecological factors that ultimately determine vector population dynamics and virus exposures in urban environments. Among these studies (Unlu et al. 2011; Dowling et al. 2013b; LaDeau et al. 2013; Dhar-Chowdhury et al. 2016; Little et al. 2017; Paul et al. 2018), competing results make it difficult to draw conclusions, as more work is needed on this understudied subject to form general consensus. Overall, we demonstrated an inverse relationship between *Aedes* infestation and neighborhood SES, with both *A. aegypti* and *A. albopictus* following this tendency. This study represents the first indication the concurrent presence of both *A. aegypti* and *A. albopictus* can be varied between socioeconomically contrasting neighborhoods. We suggest that vector surveillance and control efforts attempt to further understand and address these social determinants of vector-borne disease risk, especially in growing urban regions with considerable inequalities in wealth and infrastructure. We also present evidence that vector infestation may not be directly related to neighborhood proximity. This is not unexpected in dynamic urban regions where the shipment of goods such as used tires is frequent and uninhibited by distance, yet we look forward to more efforts designed to understand this system of potential vector dispersal. In general, the social determinants of vector-borne diseases in urban environments are highly understudied, yet they may play a considerable role in the allocation of a globally increasing risk.

ACKNOWLEDGEMENTS

We would like to thank the Smithsonian Tropical Research Institute for their financial and logistical support of this project. This includes the Mosquito Team and Milton Solano for his GIS and remote sensing assistance. Lastly, we thank the residents whose willing participation in this study was vital to its success.

FUNDING

This work was funded through a Short-Term Fellowship with the Smithsonian Tropical Research Institute.

COMPLIANCE WITH ETHICAL STANDARDS

CONFLICT OF INTEREST The authors declare that they have no conflict of interest.

APPENDIX

See Table 4.

Table 4. Ovitrap sites in each neighborhood with the Shannon land cover diversity index, patch density, and edge density in a 30-m radius

Neighborhood	Socioeconomic status	Proximity	Latitude	Longitude	Patch density	Edge density	Shannon Diversity Index
Costa del Este	High	Low	9.015805	- 79.472	14,209.74	3453.821	1.1442
Costa del Este	High	Low	9.016434	- 79.4678	8881.091	2405.994	1.0426
Costa del Este	High	Low	9.011088	- 79.4686	7815.36	1937.072	0.7571
Costa del Este	High	Low	9.009447	- 79.4714	8881.091	2475.053	0.9271
Costa del Este	High	Low	9.00822	- 79.4754	10,657.31	3743.699	1.1057
Costa del Este	High	Low	9.007788	- 79.4782	4618.167	1205.555	0.9981
Costa del Este	High	Low	9.01064	- 79.4761	13,144.01	3977.308	0.9798
Costa del Este	High	Low	9.012549	- 79.4761	15,630.72	4144.414	1.1147
Costa del Este	High	Low	9.014246	- 79.4752	22,735.59	5222.934	1.3155
Costa del Este	High	Low	9.015419	- 79.4762	7460.116	2170.681	1.319
Mean					11,403.32	3076.530	1.0703
Altos de las Torres	Low	Low	9.071937	- 79.4912	9951.912	2424.286	0.751
Altos de las Torres	Low	Low	9.072299	- 79.4877	10,177.41	2056.051	0.7398
Altos de las Torres	Low	Low	9.077618	- 79.4866	7460.116	1612.238	0.7009
Altos de las Torres	Low	Low	9.079628	- 79.4907	8526.021	2805.914	0.8194
Altos de las Torres	Low	Low	9.078095	- 79.4884	12,078.53	3127.345	0.9953
Altos de las Torres	Low	Low	9.077365	- 79.4875	15,630.72	4054.893	1.1774
Altos de las Torres	Low	Low	9.076546	- 79.486	9946.822	2472.496	0.8375
Altos de las Torres	Low	Low	9.075571	- 79.4847	15,630.72	4058.303	1.0448
Altos de las Torres	Low	Low	9.073924	- 79.4841	15,625.86	3269.57	0.9525
Altos de las Torres	Low	Low	9.072817	- 79.4841	13,379.15	2814.201	0.8833
Mean					11,840.72	2869.52	0.8901
Boca la Caja	Low	High	8.985013	- 79.508	14,200.16	3195.035	1.0084
Boca la Caja	Low	High	8.985141	- 79.5071	4534.558	1809.629	0.6342
Boca la Caja	Low	High	8.985388	- 79.5061	12,084.75	2911.999	0.7492
Boca la Caja	Low	High	8.985429	- 79.5048	3406.121	1297.846	0.8591
Boca la Caja	Low	High	8.985885	- 79.5034	6993.728	1992.513	0.508
Boca la Caja	Low	High	8.985103	- 79.504	3552.509	588.2955	0.2123
Boca la Caja	Low	High	8.984771	- 79.5036	3197.258	1069.163	0.5193

Table 4. continued

Neighborhood	Socioeconomic status	Proximity	Latitude	Longitude	Patch density	Edge density	Shannon Diversity Index
Boca la Caja	Low	High	8.98467	− 79.5047	3197.258	1545.768	0.53
Boca la Caja	Low	High	8.983383	− 79.5057	3907.76	1389.742	0.4832
Boca la Caja	Low	High	8.982938	− 79.5062	5683.38	1141.791	0.3387
Mean					6075.74	1694.17	0.5842
Punta Pacifica	High	High	8.974468	− 79.5166	2841.769	479.4064	0.4956
Punta Pacifica	High	High	8.976921	− 79.5152	5684.014	1887.661	0.8859
Punta Pacifica	High	High	8.976857	− 79.5139	7815.52	1287.429	0.5848
Punta Pacifica	High	High	8.973427	− 79.5145	6447.722	1066.377	0.6703
Punta Pacifica	High	High	8.974742	− 79.5131	6749.629	2337.787	1.0573
Punta Pacifica	High	High	8.975872	− 79.5111	9947.025	3256.088	0.9682
Punta Pacifica	High	High	8.977217	− 79.5107	6039.265	2284.974	0.9429
Punta Pacifica	High	High	8.975294	− 79.5079	4973.513	1371.837	0.689
Punta Pacifica	High	High	8.976251	− 79.5088	1421.004	444.2057	0.2177
Punta Pacifica	High	High	8.982251	− 79.5079	7813.341	1650.746	0.886
Mean					5973.280	1606.651	0.7397

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