Evaluating Potential Mosquito Breeding Sites on a University Campus

Pua Lani Yang BA; Denise C. Nelson-Hurwitz PhD; and Alan R. Katz MD, MPH

Abstract

In recent decades, mosquito-borne diseases (MBDs) such as Zika, chikungunya, malaria, and dengue have spread to more urban areas previously free of such diseases. Globalization has increased the infection potential for diseases and their vectors, placing tropical tourist destinations, such as Hawai'i, at risk for MBD epidemics. A cross-sectional study was conducted on the University of Hawai'i at Mānoa campus to assess potential mosquito breeding sites. The campus was stratified by land use designation and randomly sampled. Residential areas had the highest potential for breeding sites with high numbers of discarded plastic food and beverage containers. Recommended prevention strategies to curb littering in the residential area include awareness campaigns and encouraging collaboration between maintenance authorities to enhance oversight. This study highlights the importance of individual awareness and prevention of environment modifications that could contribute to the development of mosquito breeding sites.

Keywords

Mosquito control, environment and public health, cross-sectional study

Abbreviations and Acronyms

MBD = Mosquito-borne disease
UHM = University of Hawai'I at Mānoa

Introduction and Purpose

Mosquito-borne diseases (MBDs) are among the deadliest and most well-known vector-borne diseases and include chikungunya, dengue, Zika, and malaria.[1] On a global scale, MBDs, such as malaria, are responsible for nearly 400 000 deaths per year.[1] These diseases disproportionately burden the poorest populations with inadequate health care infrastructure. Urbanization in previously untouched natural environments has been shown to create novel genetic opportunities for mosquito species to adapt to urban conditions successfully.[2] The rapid modernization of low and middle-income countries has also increased opportunities for interaction between human and mosquito species, thus increasing the global incidence of MBDs. Further, recent outbreaks have shown that urban areas are highly effective breeding sites for mosquitoes, which increases the likelihood of disease transmission.[3] The establishment of disease-transmitting mosquitoes in dense human populations is a significant threat to public health; it is estimated that 3.9 billion people globally are at risk of an MBD epidemic.[4]

Hawai'i is of particular concern for MBD outbreaks because the temperate climate allows for a year-round breeding season. *Aedes aegypti,* the mosquito that transmits yellow fever, has not yet sustained a widespread population on O'ahu (the most densely populated island). In contrast, *Aedes albopictus*, the Asian tiger mosquito, is found on nearly all Hawaiian Islands.[5] Both mosquito species pose a threat to community health. While a consistent, isolated population of *Ae. aegypti* only exists on Hawai'i island; it has recently been found on O'ahu.[5] The dominant mosquito species in Hawai'i, *Ae. albopictus*, is a vector for dengue, chikungunya, Zika, and other arboviruses. In the past, *Ae. albopictus* has been responsible for outbreaks of locally-transmitted dengue in Hawai'i.[6] There is the potential for large MBD outbreaks if *Ae. aegypti* were to establish a population on O'ahu.[5]

Currently, the only ongoing mosquito surveillance program in the state of Hawai'i is at Daniel K. Inouye International Airport, under the direction of the Centers for Disease Control and Prevention.[5] The airport is a major site for international and domestic human interaction. According to the State of Hawai'i Department of Transportation, more than 20 million visitors pass through the Daniel K. Inouye International Airport every year.[7] The Hawai'i State Department of Health estimates that approximately seven confirmed cases of dengue are imported into Hawai'i annually.[8] While autochthonous transmission of dengue is uncommon, the risk exists if an infected individual is bitten in Hawai'i.[9]

While *Ae. aegypti* has a greater preference for biting humans than *Ae. albopictus*, both species are well-adapted to oviposit in small objects containing water left around human habitats.[10,11] This can have significant consequences in Hawai'i where rain is expected year-round. Potential mosquito habitats in Hawai'i include any cup-like plant, garden pots, refuse, tires, construction materials, and pools created by intent or poor irrigation.[10,12,13] Bromeliads, commonly used in landscaping, are of particular concern in Hawai'i because they are a well-established breeding site for all mosquitoes due to their cup-like axis.[13] Failure to maintain urban environments due to human oversight has also been cited as the main factor in developing urban mosquito populations.[14]

The University of Hawai'i at Mānoa (UHM) campus is a highly trafficked environment for most of the year, is heavily landscaped, and receives rainfall year-round, which points to its potential as an outbreak site. UHM Landscape Services is responsible for the maintenance of the main campus grounds, which does not include athletics grounds, student housing, and faculty housing.[15] According to the UHM Landscaping Services, maintenance of potential mosquito breeding sites is done on a "reactive" basis, rather than a proactive one (personal communication, Mr. Jason Ramelb, 2018). Although using cup-like plants, such as bromeliads, for landscaping is avoided on campus, there are many urban and natural environmental intersections that may promote mosquito breeding and MBD transmission. The purpose of this study was to conduct a point-in-time landscape analysis to assess the potential risk of establishment of mosquito breeding sites on the UHM campus.

Methods

"Potential mosquito breeding sites" were defined as any container-objects that could hold any amount of water for a prolonged period. The literature further defined this criterion as objects commonly found to breed mosquitoes in Hawai'i, such as the bromeliad plant, tree holes, and construction materials.[10,12,13] Other objects not specific to Hawai'i included empty planters, trash, tires, broken pipes, and pools.[12,14]

The study area was categorized using the UHM Landscape Master Plan,[15] which stratified the campus into the following designations: courtyard, streetscape, civic space, special/unique, residential, interstitial/connective, natural area, and undeveloped area. The natural and undeveloped areas were not sampled because they included forests and a stream, therefore impractical to assess with the limited resources of this study. Within each land use designation category, individual areas were numbered. Using a random number generator, one area was randomly selected to represent the land designation. A stratified random sampling technique was done to optimize the selection of a representative sample from each land designation category.[16]

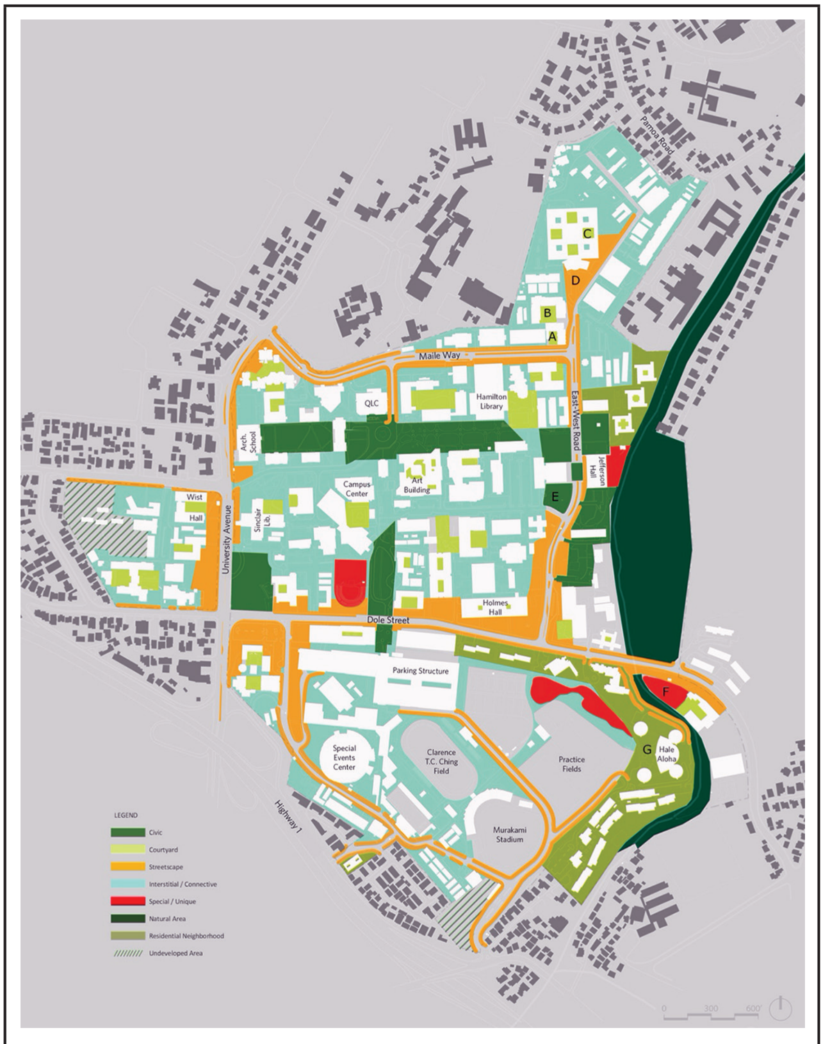

Figure 1. Map of the University of Hawai'i at Mānoa Campus Stratified by Land Use Designation according to the University of Hawai'i at Mānoa Landscape Master Plan[a]

[a]Sasaki Associates Inc. The University of Hawai'i at Mānoa Landscape Master Plan. https://web.archive.org/web/20161101172031/http://manoa.hawaii.edu/planning/LMP_May2012.pdf. Published 2012. Accessed May 28, 2020.

Figure 2. Standardized Systematic Area Sampling Methodology for Mosquito Breeding Site Survey, University of Hawai'i at Mānoa Campus, July-August 2018

Each area was surveyed in a standardized manner over a 3-week period between July 25, 2018 to August 8, 2018 at 12:00 PM Hawai'i Standard Time. For each area, the surveyor started at one corner and walked heel to toe in a straight line until a land border was reached. Once the border was reached, the surveyor turned 90 degrees, walked forward 18 inches, turned another 90 degrees, and headed back in the opposite direction, repeating the heel to toe survey. The surveyor would then pause to take notes and pictures of the observation thus far. This process was repeated until the designated area was completely assessed.

A new sample area was assessed twice weekly. After data collection, the surveyor tallied the number of each type of potential mosquito breeding objects and categorized each object as either "natural" (eg, plant, tree root depression, coconut husk, pond)[2,13,14] or "urban" (eg, plastic cup, soda can, trash, planters).[2,3,14] This study did not include human participants or the use of animals; hence it was exempt from IRB or IACUC approval.

Results

The courtyard land designation consisted of several separate areas (courtyards A, B, & C on the map). In Courtyard A, 8 empty planters, a broken water pipe, 11 open kukui nut shells, 4 open plastic containers, a patch of bromeliad plants, and 2 human-made ponds were observed as potential mosquito-breeding sites. A few of the planters, as well as the patch of bromeliads, were well-shaded. In general, Courtyard A appeared to be less maintained by the landscaping and maintenance crews than the other courtyards based on the amount of natural waste on the ground. Courtyard B appeared to be well-maintained, reflected by the lack of natural waste on the ground and the overall cleanliness. A few novel potential mosquito-breeding sites were observed in dried coconut shells and tree husks that held water. One of the landscaped trees in the courtyard, Madre de cacao (*Gliricidia sepium*), showed natural exposed root depressions that qualified as a novel breeding opportunity. Courtyard C was generally well-maintained and did not have as many tables and benches as courtyards A and B. Three open plastic bags, several patches of mother-in-law's tongue (*Sansevieria trifasciata*), two structural depressions, and one open plastic container were observed. The 3 courtyards had a total of 32 natural objects and 10 urban objects that might serve as mosquito breeding sites. No mosquito larvae were observed inside the objects.

The streetscape ("D" on the map) consisted of the paved road and sidewalk from the intersection of East-West Road and Maile Way to the portable classrooms. A total of 1 natural container, a coconut shell, and 3 plastic containers in the form of 2 open planters and a plastic drink cap were observed. The streetscape was well-maintained and was not heavily trafficked during the time of observation. The streetscape had a total of 1 natural object and 3 urban objects. No mosquito larvae were observed inside the objects.

The civic spaces ("E" on the map) had a large number of natural potential mosquito-breeding sites due to the large banyan trees in the area. One plastic container, 2 bottle caps, and 1 plastic wrapper were observed. The 5 Chinese Banyan trees (*Ficus microcarpa*) in the area showed exposed root depressions and deep, container-like depressions within the tree trunks. A total of 29 natural and 4 urban potential mosquito-breeding sites were observed. Due to construction, the total area observed for the civic spaces land designation was smaller than the area originally planned to be sampled.

The special land designation area ("F" on the map) consisted of the lo'i (a taro patch), which is detached from the main campus. The area was well-maintained, with no observable trash. Although the lo'i is defined by its water ponds, there was a continuously running stream of water to interrupt the ponds. A flock of ducks was also observed wading into the ponds. A total of 21 open, gourd-like shells were observed under the lone La'amea tree (*Cresentia cujete*). The fallen gourd-like fruit provided many natural mosquito-breeding opportunities. No mosquito larvae were present inside the gourds. There were no urban objects observed in the special land designation area.

The residential land designation ("G" on the map) consisted of the student housing apartments detached from the main university campus. A total of 35 open plastic containers were observed and 2 empty planters, 23 soda cans, and several piles of disintegrating plastic bags. There were 68 total urban potential mosquito-breeding sites and no natural potential mosquito-breeding sites. Significant piles of plastic waste were observed on the opposite side of the fencing that separates the student housing apartments from the athletic complex. Due to earlier precipitation, many of the open plastic objects contained rain-water and insects. At the time of observation, students were in the process of moving back into student housing. This resulted in more foot traffic in the residential area than the other parts of the university campus.

Figure 3. Pictures of Potential Mosquito Breeding Sites Observed During the Study Period, University of Hawai'i at Mānoa Campus, July-August 2018

Clockwise from bottom left: empty gourd-like fruits from the La'amea tree observed in the lo'i; empty planters and water-containing plastic cups observed in the Courtyards; a patch of well-shaded bromeliad plants observed in the Courtyards; a plastic container with rain water and cockroaches observed in the Residential area.

Table 1. Observed Potential Mosquito-breeding Sites, University of Hawai'i at Mānoa Campus Stratified by Container Type and by Land Use, July–August 2018

Container Type	Courtyard	Streetscapes	Civic Spaces	Special	Residential
Natural Objects					
Pond	2	0	0	0	0
Tree root depressions	4	0	29	0	0
Kukui nut husk	11	0	0	0	0
Coconut husk	3	1	0	0	0
Other container plant	7	0	0	21	0
Bromeliad	5	0	0	0	0
Subtotal	**32**	**1**	**29**	**21**	**0**
Urban Objects					
Planter	8	2	0	0	2
Plastic cup[a]	1	1	3	0	35
Soda can[a]	0	0	0	0	23
Trash[a]	0	0	1	0	8
Broken water pipe	1	0	0	0	0
Subtotal	**10**	**3**	**4**	**0**	**68**
Total	**42**	**4**	**33**	**21**	**68**

[a] Objects found on the ground.

Discussion

Each land designation displayed varying levels of potential mosquito breeding grounds. Overall, the residential area demonstrated the highest potential, with a total of 68 observed breeding locations. In contrast, the streetscapes area demonstrated the least potential, with a total of 4 observed breeding locations. The top 3 areas of counted potential breeding locations (in order) were the residential, courtyard, and civic space areas. The types of objects counted varied according to the area sampled. Of the top 3 areas, the most common possible breeding sites observed were plastic containers, soda cans, tree root depressions, and other container-like plants. The counted objects in the residential area, which was the most trafficked area at the time of observation, were almost exclusively plastic containers and soda cans. This points to a high level of human interaction with the natural environment in this area compared to other observed areas. In comparison, the courtyard area had greater heterogeneity in the types of counted objects. Courtyard A had the highest variation and total count of objects compared to the other courtyards. According to the "Landscaping Master Plan" such as ponds and bromeliads, the presence of highly discouraged landscaping elements, as well as the general amount of fallen plant matter on the ground, demonstrates potential mosquito breeding areas that could be prevented, managed, or maintained in a more optimal manner.

Limitations

During the observation period, there was significant construction activity to re-pave large areas of the campus, which closed off many areas to the public. This resulted in re-selecting the interstitial/connective area sample because the original selection was unable to be accessed. This construction also reduced the size of the total area observed for the civic spaces land designation. Also, many of the selected areas were altered in a way that did not fully represent the area originally depicted on the Landscaping Master Plan. A few of the sample areas were very large and could not be surveyed in one day. For those areas, they were broken into smaller areas to be surveyed on different days. A single observer conducted the land use survey in each designated area, so we were unable to assess or measure inter-observer reliability, but the use of a standardized survey strategy helped to optimize validity.

The time of observation for all areas was done during summer break, which greatly reduced the amount of foot traffic on campus. Had the observation been during the Fall or Spring semesters, the observed counts of potential breeding sites may have been significantly higher. Due to the nature of the observation, the number of counted objects could have been influenced by human error. For example, the observer may have miscounted the observed objects. It is also possible that visually obscured sites (eg, sites extending underground) may have been missed. Lastly, due to the cross-sectional nature of the study, the findings are reflective of the dates of observation.

Conclusion

The land designation areas with the highest potential risk for establishing mosquito breeding sites are the courtyard and residential areas. Interventions to address the prevention and removal of high-risk objects should consider the type of objects and who is responsible for their disposal in that area. Mosquito-breeding development risk awareness campaigns should be targeted towards the campus as a whole and specifically towards faculty members, staff, and students working in buildings with courtyards and other natural areas. Due to seemingly limited maintenance in those areas, individuals in such departments should be aware of what natural elements pose the greatest risk and how to store container objects outside to reduce potentially dangerous environment modifications. Greater collaboration between the UHM landscaping and maintenance division and academic departments (eg, Department of Plant and Environmental Protection Sciences) is also encouraged to assist in the surveillance and prevention of mosquito breeding sites and strengthening pest-management plans. The UHM landscaping services do not have jurisdiction in the residential areas and rely on contracted services to maintain these spaces. The number of discarded food and beverage containers, as opposed to the number of natural and infrastructural potential breeding sites, clearly incriminates human activity. While other campus areas only operate during the day, residential campus life continues well into the night, when maintenance services are unavailable. Therefore, to prevent the establishment of mosquitoes and other pests in the residential area, mosquito-borne disease awareness should be targeted towards students living on campus. Awareness campaigns should stress the importance of individual action and proactive approaches to reduce mosquito-breeding sites. Another suggestion is to increase the number of trash receptacles around the residential areas. This would deter campus residents from discarding trash in areas that are not maintained, such as beyond the fence that separates the residential area from the athletic complex.

To prevent future MBD epidemics, it is highly encouraged to implement MBD awareness campaigns aimed at faculty, students, and staff in high-risk areas to promote individual preventive action.

Global trends show that human encroachment into natural areas, driven by fast urban development, has influenced the emergence of mosquito-borne diseases in previously unseen areas.[2] Hawai‘i is unique because of its location, environment, and popularity as a travel destination. Acting as a microcosm for the density and diversity of the human population on O‘ahu, the observation of potential mosquito breeding sites on the UHM campus shows that the risk of mosquito population establishment increases with the lack of individual awareness and the absence of a comprehensive maintenance plan in high trafficked areas. This has direct implications for other tropical regions with similar human-urban environmental interactions.

Conflict of Interest

None of the authors identify a conflict of interest.

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Authors' Affiliation:
- Office of Public Health Studies, University of Hawai‘i at Mānoa, 1960 East-West Road, Honolulu, HI

Correspondence to:
Denise C. Nelson-Hurwitz PhD; Office of Public Health Studies, University of Hawai‘i at Mānoa, 1960 East-West Road, Honolulu, HI 96822; Email: denisene@hawaii.edu

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