Breeding Grounds by the Shore: A Precision Public Health Analysis of Mosquito Vectors in the Fishing Villages and in Town Housing Areas of Nakhon Si Thammarat

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Abstract

This study conducted high-resolution larval surveillance in a fisherman's village and urban housing area in Thailand, integrating citizen science data from the GLOBE Observer app with taxonomic identification. Results revealed a distinct partitioning of key vector species, with Aedes species significantly associated with artificial containers (particularly water storage and discarded tires). In contrast, *Anopheles/Culex* species were predominant in natural sites. There were contrast in the type of containers were identified as high-productivity "super-spreader" habitats, and entomological indices exceeded WHO risk thresholds. The findings underscore the need for habitat-specific, community-integrated control strategies and highlight the value of citizen science in informing targeted vector management in high-risk coastal environments.
Keywords: Mosquito surveillance, larval habitat, citizen science, GLOBE Observer, coastal community, fishing village, Aedes aegypti, Anopheles, container breeding, disease risk, vector control, Thailand

1. Introduction

Mosquitoes remain globally significant vectors of numerous debilitating and life-threatening pathogens, including viruses responsible for Dengue Fever, Zika, Chikungunya, and parasites causing Malaria, thereby posing a continual threat to human health security and economic stability, particularly in tropical and subtropical regions (Ryan et al., 2020; WHO, 2021). The escalating challenges presented by these vector-borne diseases are inextricably linked to the successful propagation and dispersal of their mosquito vectors. Effective disease prevention and control strategies critically depend on thorough vector surveillance, which is most efficiently targeted at the larval stage—the immobile, aquatic phase of the mosquito life cycle, as its characteristics and habitat specificity provide a crucial window for intervention (Clements, 2017).

Coastal communities, such as fisherman villages, are often characterized by unique ecological and socio-economic dynamics that exacerbate the risk of arboviral and parasitic transmission. The proximity to both marine environments and freshwater and brackish water sources, coupled with specific occupational practices (e.g., fishing, aquaculture), creates a diverse mosaic of potential mosquito breeding habitats (Bockarie et al., 2018). These environments typically support two significant categories of breeding sites: artificial breeding sites (ABS) and natural breeding sites (NBS). ABS, often anthropogenically created or modified, includes discarded or functional water storage containers, abandoned boat parts, tyres, and other refuse that collect rainwater near human dwellings. These sites predominantly favour container-breeding species such as *Aedes aegypti* and *Aedes albopictus*, primary vectors of Dengue and Zika viruses (Powell & Tabachnick, 2021). Conversely, NBS encompass naturally occurring environments like coastal mangroves, freshwater swamps, rock pools, and natural puddles. These natural settings often harbour species from the genera Anopheles (Malaria vectors) and *Culex* (vectors of Japanese Encephalitis and West Nile Virus), whose specific physiological tolerances enable them to exploit the variable salinity and ecological composition found in coastal and peri-domestic areas (Kudom et al., 2019).

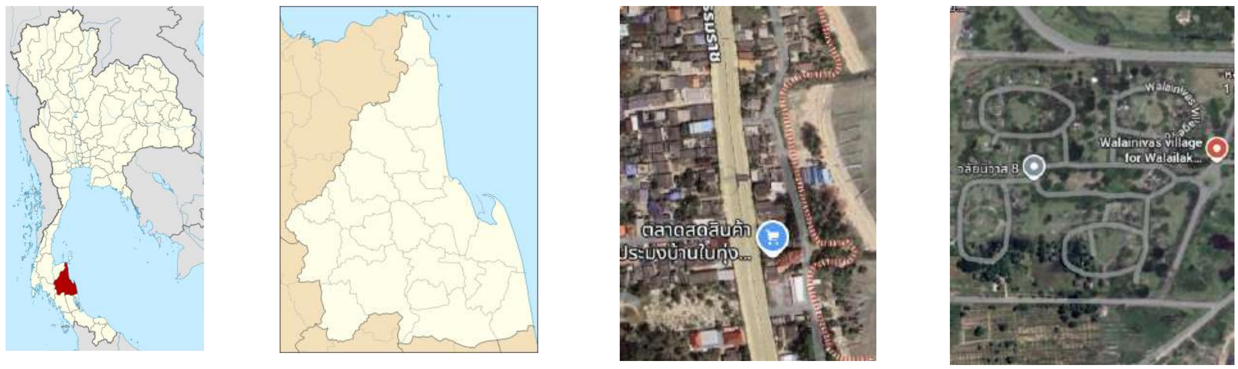
A gap in the current understanding of disease risk in these high-risk coastal communities is the lack of systematic, high-resolution data on the specific mosquito species that use different habitat types. Each mosquito species exhibits unique oviposition preferences that determine which control methods (e.g., source reduction, larviciding) are most effective. For instance, interventions targeting ABS are crucial for managing *Aedes*-driven diseases, while strategies focusing on NBS are more pertinent for controlling *Anopheles* or *Culex* populations (Midega et al., 2022). Failure to accurately identify and differentiate the vector species thriving in both ABS and NBS can lead to misdirected public health efforts, inefficient resource allocation, and persistent transmission cycles. Furthermore, environmental changes associated with climate variability and rapid urbanization disproportionately affect coastal areas, potentially altering the availability and characteristics of both ABS and NBS, thereby influencing vector distribution and species composition (Tiwari et al., 2020).

This study leverages the citizen science framework of the GLOBE Observer: Mosquito Habitat Mapper to conduct a high-resolution analysis of mosquito breeding patterns in selected fishing communities (GLOBE Program, 2023). Citizen science initiatives provide a reliable and scalable means of augmenting national surveillance systems by engaging students and local communities to collect real-time, widespread data (Bonney et al., 2016; Palmer et al., 2017). By integrating larval surveillance data identified using standard taxonomic keys (Rattanarithikul et al., 2005) with advanced entomological metrics, this research aims to: (1) map the distribution of key vector species across artificial and natural habitats; (2) identify high-productivity containers specific to the fishing industry; and (3) assess local disease transmission risks. The findings will contribute to a deeper understanding of mosquito ecology and inform the development of evidence-based, community-integrated source reduction strategies (Horstick et al., 2010).

2. Materials and methods

2.1 Study site

In December 2025, a community in Ban Nai Thung and Walailak University, Nakhon Si Thammarat Province, southern Thailand (8.6538° North, 99.9017° East) was surveyed for mosquito larvae. Nakhon Si Thammarat Province has three seasons: summer (mid-February to mid-May), rainy season (mid-May to mid-October), and winter (mid-October to mid-February).



Map of Thailand (a) | Map of Nakhon Si Thammarat (b) | Map of Ban Nai Thung (c) | Map of Walailak University (d)

Figure 1. (a) Map of Thailand, (b) Map of Nakhon Si Thammarati, (c) Map of study sites at Ban Nai Thung, and (d) Map of Walailak University

2.2 Sampling of mosquito larvae.

Figure 2. GLOBE Observer: MHM App

2.2.1 Survey the Ban Nai Thung area, then collect samples of larvae and larval predators for classification.

2.2.2 Inspect every container, both with and without water. Measure the pH and temperature of the water in the container.

2.2.3 Measure the amount of water in the container and check whether it has a lid.

2.2.4 Scoop up and put living things, including mosquito larvae and predators, into plastic bags.

2.2.5 Use the MHM app to find the latitude and longitude coordinates of the area where mosquito larvae were found and save the information in the GO MHM app (Figure 2).

2.2.6 The captured organisms were returned to be classified as species and recorded.

2.3 Conceptual Framework

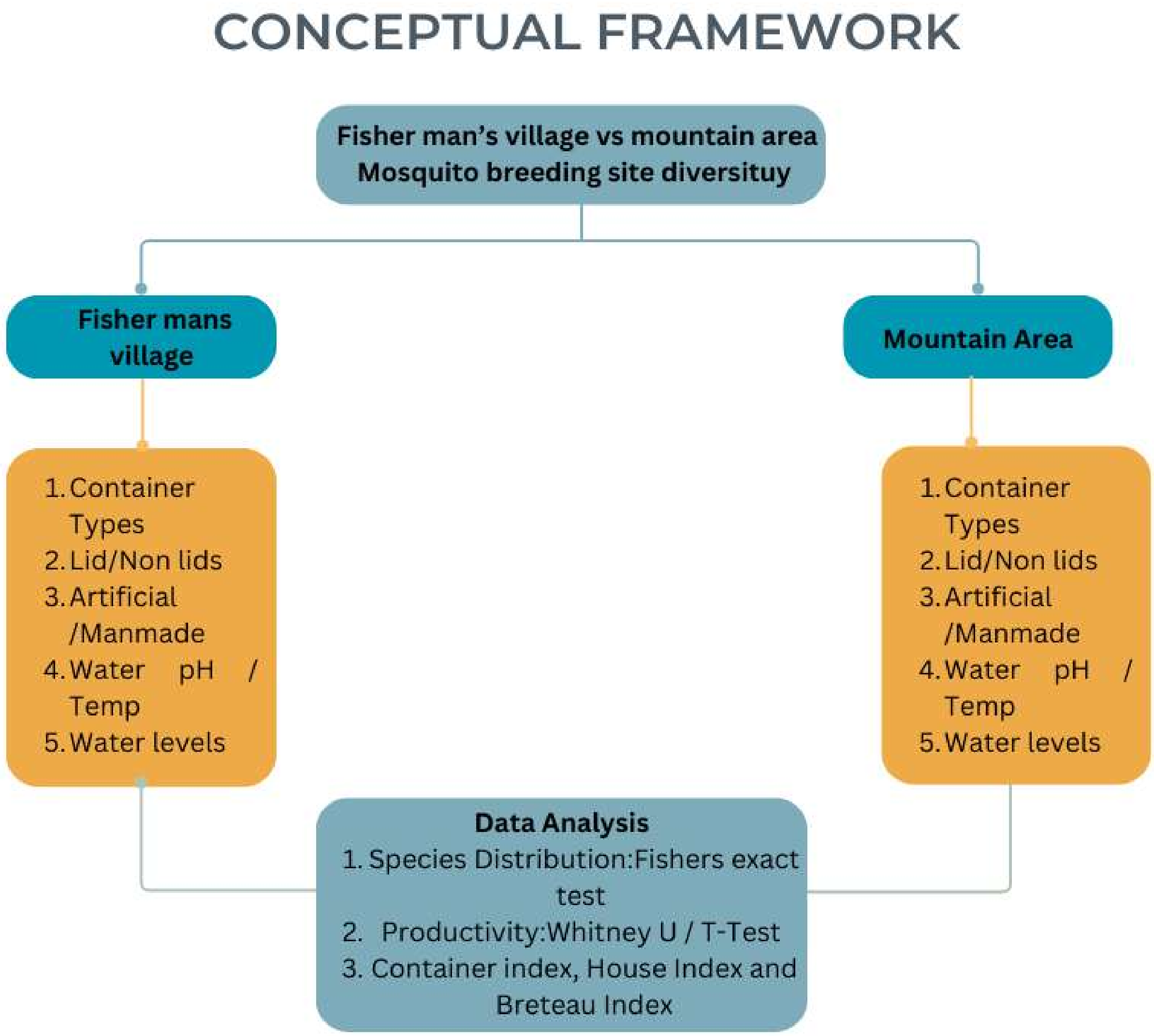


Figure 3. Conceptual framework of this study

2.4 Data collection

For this study, data were obtained from the GLOBE database for Ban Nai Thung village and through field observations conducted by students using GLOBE mosquito mapper app Walailak University and Ban Nai Thung housing area in Nakhon Si Thammarat. The GLOBE mosquito data of village was categorized by checking the latitude and longitude provided in the data set which was supplemented by field data. Students were involved in collecting data on mosquito larvae, environmental factors such as water temperature and pH, and in identifying mosquito species. The field surveys were conducted in multiple outdoor containers across the afore mentioned areas, ensuring that the data captured a range of ecological conditions. The data were then analyzed to assess differences between the village and urban in analyzing the species distribution productivity and the threat level. We used the GLOBE Observer: MHM app to determine the latitude and longitude coordinates of the locations where mosquito larvae were found.

2.5 Entomological studies

This study integrates mosquito larval data collected directly from the Walailak University housing area and Ban Nai Thung, with data from the GLOBE Mosquito Habitat Mapper for at Ban Nai Thung. Larval collection followed a standardized protocol: smaller containers were emptied and filtered, whereas larger containers were sampled with nets to ensure comprehensive coverage (Indriyani et al., 2024). Collected larvae were preserved and identified as species using Rattanarithikul and Panthusiri's keys. Early instar larvae and pupae were excluded due to identification challenges. The study included 360 container categories. Plastic water containers were further divided into two groups: large plastic containers for water storage (>100 L) and plastic bottles (0.5–2.0 L). Earthen jars were also classified into two categories: small earthen jars with a volume of ≤100 L and large earthen jars exceeding 100 L in volume. The GLOBE data, which provided broader coverage, were used to analyze mosquito species distributions, breeding-site preferences, and container and house indices across the two areas. Combining these datasets allowed a more comprehensive understanding of mosquito ecology and the factors affecting the mosquito adapting to urbanization

2.6 Statistical analysis

Statistical analysis was performed in Python, with students guided in selecting tests appropriate for small datasets. 40 Households (1) Species Distribution: To determine if specific mosquito species prefer artificial over natural habitats, Fisher's Exact Test was used. This test was chosen over the Chi-Square test to ensure accuracy given the study's small sample size. (2) Productivity: To identify "super-spreader" containers, the Mann-Whitney U Test was employed to compare the median number of larvae found in manmade versus natural habitats. This non-parametric test was selected because larval data typically do not follow a standard "bell curve" distribution. (3) Risk Assessment: Disease transmission risk was assessed by calculating the Container Index (CI) and House Index (HI). To account for the uncertainty inherent in a small sample size, confidence intervals were calculated for each index, enabling a scientifically rigorous comparison with World Health Organization (WHO) risk thresholds. The visualizations were made using google sheets.

1. Container Index (CI): This measures the percentage of water-holding containers infested with larvae. It indicates the extent of breeding among the containers inspected.

$$CI = \left(\frac{\text{Number of containers with larvae or pupae}}{\text{Total number of containers inspected}}\right) \times 100$$

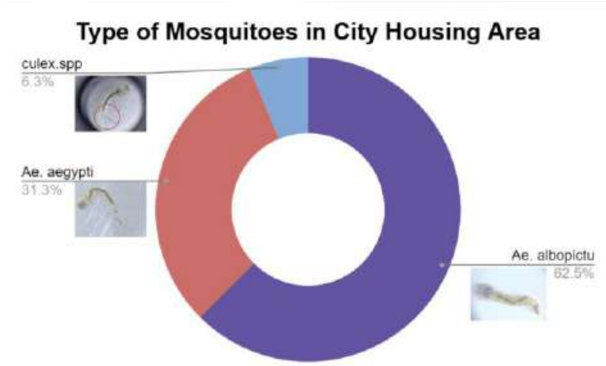
2. House Index (HI): This measures the percentage of water-holding containers infested with larvae or pupae. It indicates the extent to which the mosquito population is distributed across the community.

$$HI = \left(\frac{\text{Number of houses with at least one positive container}}{\text{Total number of houses inspected}}\right) \times 100$$

3. Results

3.1 Species diversity in the Village and the City

(a)



(b)

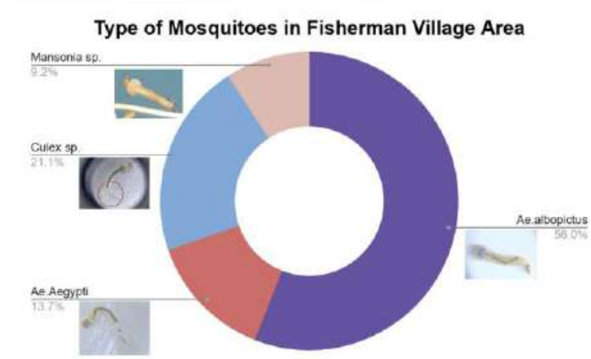


Figure 4. Mosquito diversity and locations. (a) City housing area and (b) fisherman village, Nakhon Si Thammarat, Thailand

(a) The species composition data reveal a clear dominance hierarchy within the sampled urban mosquito population, with *Aedes albopictus* constituting the majority of specimens (62.50%), followed by *Aedes aegypti* (31.25%), and a small proportion of *Culex* spp. (6.25%). This distribution indicates that *Ae. albopictus* is the most prevalent and likely the primary container-breeding vector in this habitat. Combined with the earlier finding of a significant preference for artificial containers, its numerical dominance underscores it as the key target for source-reduction campaigns, while the notable presence of *Ae. aegypti* denotes a secondary but essential vector risk that requires concurrent management.

(b) The relative abundance data reveal a clear hierarchy among the urban container-breeding mosquitoes, with *Aedes albopictus* being the overwhelmingly dominant species, comprising 56% of the collected specimens. *Culex* sp. was the next most prevalent at 21.1%, followed by *Ae. aegypti* at 13.7%, and by *Mansonia* sp. at 9.2%. This prevalence structure indicates that *Ae. albopictus* is not only highly adapted to the available artificial habitats but also the primary target for vector control in this environment, while the significant co-occurrence of *Ae. aegypti* and *Culex* sp. highlight a complex multi-species vector community that requires an integrated management approach

3.2 Species-Specific Breeding Site Selection in Village and City Housing Areas

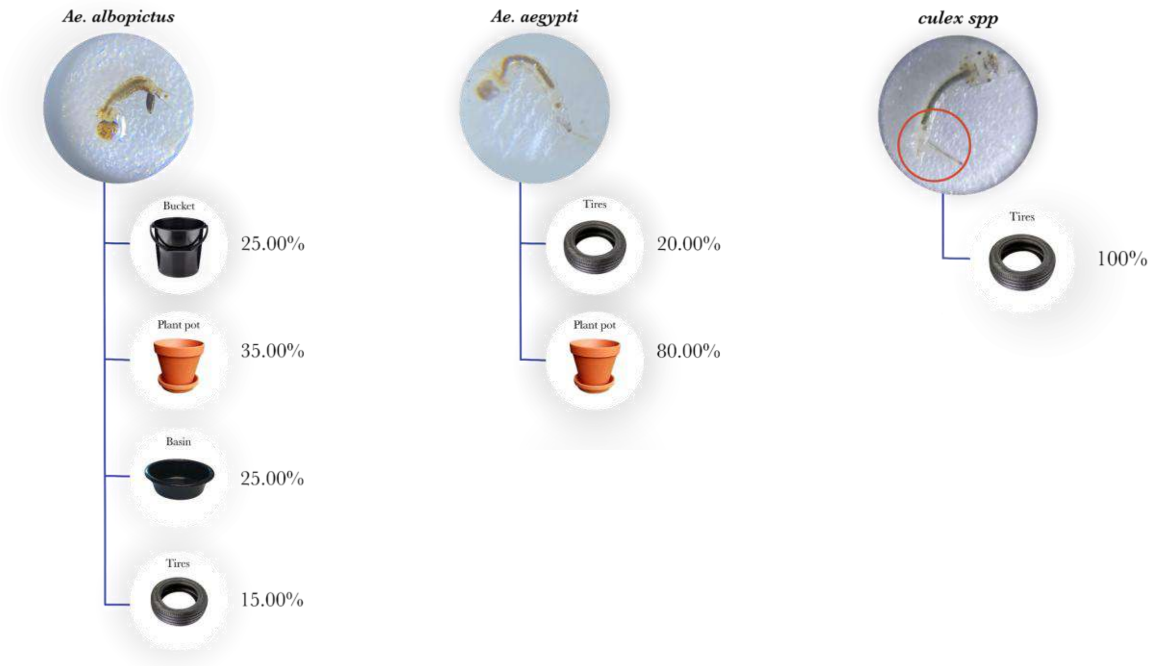


Figure 5. Types of Manmade Container Types in City Housing Areas

In the urban environment of this study, all collected mosquitoes were found exclusively in artificial containers, with species-specific preferences for particular container types emerging: *Ae. albopictus* utilized a variety of receptacles, most frequently plant pots (35%), followed equally by buckets and basins (25% each), and tires (15%); *Ae. aegypti* displayed a strong focus on plant pots (80%), with the remainder in tires (20%); while *Culex* spp. was found exclusively in tires (100%). This fine-scale partitioning indicates that even within the broader category of artificial habitats, each species occupies distinct niches, necessitating precisely targeted source reduction—prioritizing plant pots for *Aedes* control and tires for *Culex* management.

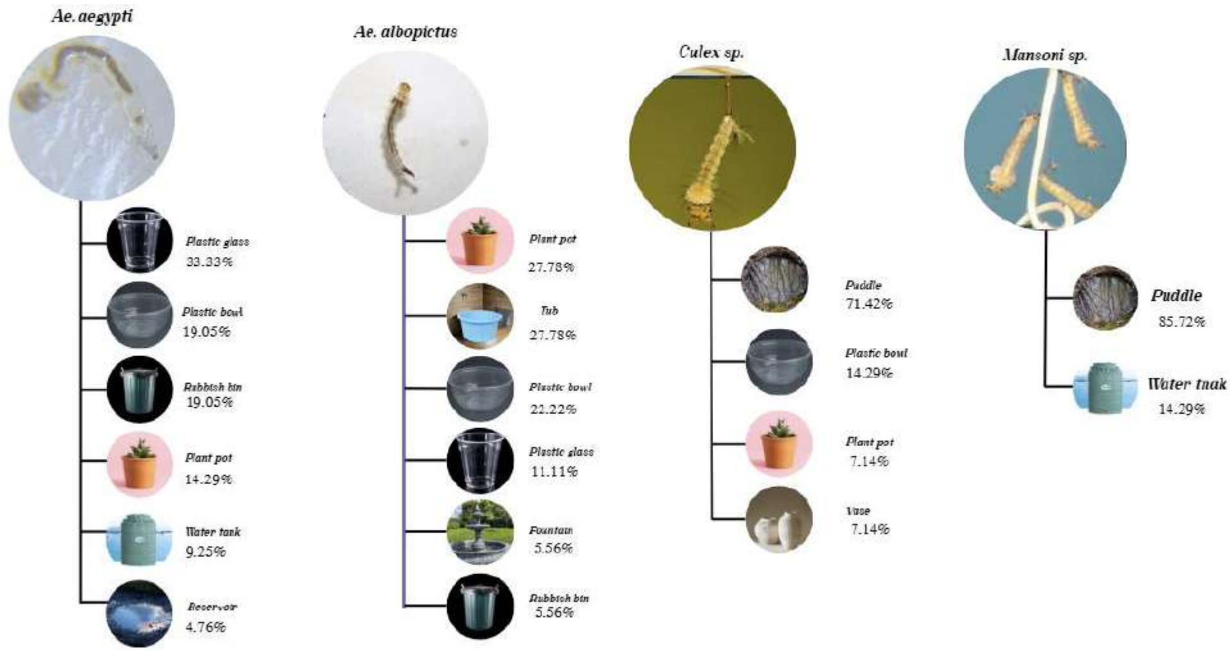


Figure 6. Types of Manmade Container Types in Fisherman's Village

The analysis of breeding-site preferences reveals a distinct ecological separation between species found in natural groundwater and those found in artificial containers. **Puddles** demonstrated the highest overall preference intensity, serving as the overwhelming choice for non-*Aedes* species; specifically, 85.72% of *Mansonia* sp. and 71.42% of *Culex* sp. were identified in these habitats.

In contrast, the primary dengue vectors strictly preferred artificial containers. ***Ae. aegypti*** showed a specific affinity for plastic glasses (33.33%) followed by plastic bowls (19.05%), while ***Ae. albopictus*** equally favored plant pots and tubs (27.78% each). When considering "universal" risk, **plant pots** and **plastic bowls** emerged as the most shared environments; these two container types hosted three different species (*Ae. aegypti*, *Ae. albopictus*, and *Culex* sp.), making them critical targets for broad vector control strategies.

Table 1. Species Preference of breeding sites in the Village (Fisher's Exact test)

Species	p-value	Significance (α=0.05)	Preference Indicated
Ae. albopictus	**0.024**	Significant	**Man Made**
Culex sp.	**0.019**	Significant	**Natural**
Mansonia sp.	**0.033**	Significant	**Natural**
Ae. aegypti	0.11	Not Significant	(Trend toward Man-Made)

The results of Fisher's Exact Test reveal distinct and statistically significant habitat preferences among the identified species: *Aedes albopictus* exhibited a strong, significant preference for artificial containers, whereas both *Culex* sp. and *Mansonia* sp. showed a substantial preference for natural habitats. Although not statistically significant due to the sample size, all collected *Aedes aegypti* specimens were found in artificial containers, indicating a pronounced trend that warrants further investigation. These findings underscore a clear species-specific division in breeding-site selection, with direct implications for targeted vector-control strategies.

3.3 Super-Spreader containers

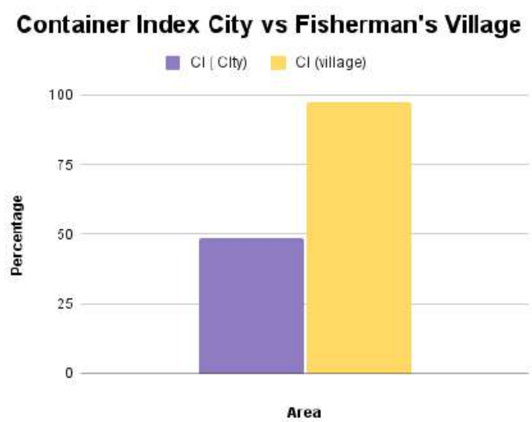
Table 2: Village Super spreader containers

Comparison	Median (Man Made)	Median (Natural)	U-statistic	p-value	Significance (α=0.05)
Artificial vs Natural	20	35	286.5	0.0406	Significant

The Mann-Whitney U test revealed a statistically significant difference between habitat types ($U = 286.5$, $p = 0.0406$), with the median value for the measured variable in natural habitats (35) being substantially higher than that in artificial habitats (20), indicating that natural breeding sites were significantly more productive or contained greater larval abundance in this study.

3.4 Container Index and House Index

(a)



(b)

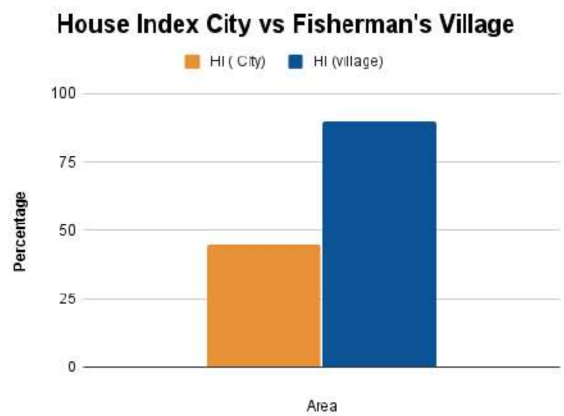


Figure 7. Container index and locations. (a) City housing area and (b) fisherman village, Nakhon Si Thammarat, Thailand

Based on the provided data, a clear and stark contrast in mosquito breeding-site prevalence emerges between the city area and Fisherman's Village, as measured by two standard entomological indices.

1. Container Index (CI)

   The Container Index reveals a dramatic difference in the proportion of water-holding containers that serve as active mosquito breeding sites. In the City area, 48.4% of surveyed containers contained larvae. This is a high figure, indicating that nearly half of all potential container habitats are productive. However, the situation in the Fisherman's Village is extreme, with a CI of 97.29%. This near-saturation level means that virtually every available container in the environment is a functional breeding ground, suggesting an almost complete lack of effective container management or larval source reduction.

2. **House Index (HI)**

   The House Index, which measures household-level risk, shows a similar pattern of disparity. In the City, 45% of inspected houses had at least one infested container, representing a significant risk for disease transmission at the community level. In contrast, the Fisherman's Village exhibits a critical HI of 90%. This indicates that the overwhelming majority of households (9 out of 10) are harboring breeding sites, placing nearly the entire community at direct and consistent risk of exposure to mosquito-borne pathogenesis

In summary, while the city area shows concerningly high levels of container infestation and household risk, Fisherman's Village is experiencing an epidemic-level breeding scenario. The indices for the village (CI ~97%, HI 90%) indicate an environment in which mosquito production is ubiquitous, necessitating urgent and intensive vector control interventions focused on community-wide container removal and management.

4. Discussion

4.1 Urbanization as a Driver of Vector Proliferation and Community Shift

The dominant presence of container-breeding *Aedes* species in your urban and peri-urban sites is not an isolated finding. Research from Guangzhou, China, demonstrated that urbanization significantly increases the availability of artificial larval habitats for *Aedes albopictus*, leading to higher mosquito density, faster larval development, and longer adult lifespans (Liu et al., 2020). This creates a "feedback loop" where urban environments, rich in plastic waste and water-holding containers, directly enhance the vectorial capacity of these mosquitoes.

Furthermore, your observation of *Aedes aegypti* being more prevalent in the City, while *Ae. albopictus* dominates the Village and reflects a known ecological gradient. Studies in Côte d'Ivoire show that intense urbanization often correlates with a simplification of the mosquito community, where the highly domesticated *Ae. aegypti* becomes the sole or dominant species, outcompeting others in densely populated cores (Zahouli et al., 2017). Your Fisherman's Village, with its extreme infestation indices, may represent a transitional or peri-urban zone where *Ae. albopictus*—an ecological generalist with high "ecological plasticity" (Kraemer et al., 2019)—currently thrives, but a further shift towards *Ae.aegypti* dominance is a distinct future risk as urbanization intensifies.

4.2 From Abundance to Risk: The Critical Role of Vector Competence

High larval indices indicate high mosquito production, but disease transmission risk also depends on mosquitoes' intrinsic ability to acquire and transmit viruses, known as vector competence. Here, the species composition you documented is crucial. *Aedes aegypti* is widely regarded as the most efficient urban vector for dengue, Zika, and yellow fever due to its strong preference for human blood and for indoor biting. In contrast, *Ae. albopictus*, while a competent vector for chikungunya and dengue, is generally considered less efficient at transmitting certain arboviruses (Souza-Neto et al., 2019). Therefore, the significant presence of *Ae. aegypti* in the City area (31.25% of specimens) represents a potentially higher per-mosquito disease risk, despite overall lower infestation levels than in the Village. This underscores the need for surveillance programs to track not just mosquito numbers, but also species-specific shifts, as the invasion and establishment of *Ae. aegypti* in new areas can dramatically alter the epidemiological landscape.

4.3 Moving Beyond Traditional Indices: Implications for Targeted Control

The near-saturation of the Container Index (97.29%) and House Index (90%) in the Fisherman's Village exposes a core challenge. When infestation is almost universal, traditional index-based trigger thresholds for action become meaningless; this calls for a paradigm shift from reactive to proactive, geographically stratified control.

4.3.1. Stratified Intervention Based on Entomological and Socio-Ecological Profiles

Control measures must be tailored to the distinct realities of each area. A one-size-fits-all approach is inefficient. The following table summarizes a proposed stratified strategy based on your findings:

In the Fisherman's Village, the hyper-endemic conditions, characterized by a Container Index nearing 100% and a House Index of 90%, alongside an *Aedes albopictus*-dominant, multi-species community, demand an Emergency Integrated Vector Management response. This situation indicates a systemic failure of conventional container management. An effective strategy must therefore be aggressive and multi-pronged, initiating with intensive, community-wide source-reduction campaigns specifically targeting the most prolific containers, such as plastic bowls and glasses. This must be coupled with area-wide larvicide of non-removable water bodies to suppress larval populations en masse. Given the scale of the challenge, evaluating the introduction of novel biological control tools, such as the release of *Wolbachia*-infected mosquitoes to reduce disease transmission, should be a priority. Crucially, these entomological actions must be integrated with socio-ecological interventions to improve solid waste management and water storage practices and sustainably address the root environmental drivers of this proliferation.

Conversely, the City Area, with high but unsaturated infestation levels and a significant presence of the highly efficient vector *Aedes aegypti*, warrants a Precision Targeted Control strategy. Here, the focus should shift from blanket campaigns to intelligence-led actions. Control efforts can be optimized through "container-specific" public education that provides clear instructions, such as urging residents to dry plant pot saucers weekly. Resources should be allocated to focused removal drives for the identified key habitats of *Ae. aegypti*, notably tires and plant pots. Furthermore, enhanced surveillance is crucial for monitoring the establishment and spread of Ae. *aegypti* within the urban matrix, enabling rapid, localized responses to new infestations and preventing this efficient vector from reaching the catastrophic dominance observed in the village.

4.3.2. Embracing Species-Specific and Time-Targeted Tactics

Your data on species-specific container preferences (e.g., *Ae. aegypti* in plant pots, *Culex* in tires) is a blueprint for precision source reduction. Public health messaging can move from the vague "remove standing water" to specific, actionable advice like "cover water tanks and regularly scrub plant pot saucers to remove *Aedes* eggs."

Furthermore, the timing of interventions like adulticide spraying is critical. Research from the US shows that the effectiveness of adulticide applications varies dramatically throughout the day, depending on the target species' peak activity periods. For example, early evening spraying (around 9 PM) was most effective across a broad range of vectors, whereas daytime spraying had limited impact (Kummer & Wilke, 2024). Integrating such diel activity data into control schedules can vastly improve efficacy.

4.3.3. Innovating Beyond Conventional Methods

A recent meta-review highlights a sobering reality: there is often insufficient high-quality evidence to conclusively recommend many conventional dengue vector control methods (Bowman et al., 2016). This evidence gap underscores the urgent need for innovation and rigorous evaluation of new tools. Promising among these is the *Wolbachia* method, where mosquitoes infected with naturally occurring *Wolbachia* bacteria are released. The bacteria inhibit arbovirus replication in mosquitoes, reducing their ability to transmit dengue, Zika, and chikungunya (Indriani et al., 2020). This self-sustaining, biologically-based intervention could be particularly valuable in the hyper-endemic Fisherman's Village setting to sustainably lower transmission risk

Conclusion

In conclusion, this study confirms that urbanization is a potent driver of vector ecology, creating distinct risk profiles, as evidenced by the hyper-endemic dominance of *Aedes albopictus* in Fisherman's Village and the critical establishment of the highly efficient *Aedes aegypti* in the City. The findings demonstrate that relying solely on traditional density indices obscures the actual epidemiological risk, which is modulated as much by species-specific vector competence as by raw abundance. Consequently, the prevailing "one-size-fits-all" approach to vector control is inadequate; sustainable management requires a paradigm shift toward stratified, intelligence-led interventions that tailor strategies from aggressive, integrated source reduction in saturated peri-urban zones to precision targeting in urban cores to the unique entomological and socio-ecological realities of each environment.

I would like to claim IVSS badges

I make an impact

The document explicitly outlines the link between a community concern and the research inquiries, establishing connections between local and global repercussions. The students must depict how their research has positively influenced their community by providing recommendations or implementing actions derived from their findings. Exploring the ecology of mosquito larvae offers insights that can be utilized to safeguard the community against disease transmission via animal vectors, achieved by modifying or minimizing the use of specific container materials.

I am a STEM professional.

The report distinctly outlines the collaboration with a STEM professional, which bolstered the research methods, enhanced precision, and facilitated more advanced analyses and interpretations of the results. The data were analyzed using fishers exact test to compare the preffered breeding site of different species of mosquito and : To identify "super-spreader" containers, the Mann-Whitney U Test was employed to compare the median number of larvae found in manmade versus natural habitats

I am a data scientist.

The report thoroughly examines the students' proprietary data and additional data sources. Students critically evaluate the limitations of this data, draw inferences about historical, current, or future events, and leverage the data to address questions or resolve issues within the depicted system. This may involve incorporating data from other educational institutions or utilizing information from external databases. The latitude and longitude of the locations where mosquito larvae were observed were recorded using the GLOBE Observer: MHM App. This study incorporates both Globe data for the location and the collected data for the analysis

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References

1. Bockarie, M. J., Kelly-Hope, L. A., & Rebollo, M. (2018). *Elimination of lymphatic filariasis as a public health problem: Progress and challenges*. World Health Organization.
2. Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science, 25*(1), 2–16. https://doi.org/10.1177/0963662515607406
3. Clements, A. N. (2017). *The biology of mosquitoes* (Vol. 3). CABI.
4. GLOBE Program. (2023). *GLOBE Observer: Mosquito Habitat Mapper*. NASA. https://observer.globe.gov/about/mosquito-habitat-mapper
5. Horstick, O., Runge-Ranzinger, S., Nathan, M. B., & Kroeger, A. (2010). Dengue vector-control services: How do they work? A systematic literature review and country case studies. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 104*(6), 379–386. https://doi.org/10.1016/j.trstmh.2010.01.002
6. Kudom, A. A., Mensah, B. A., & Agyemang, T. K. (2019). Characterization of mosquito larval habitats and assessment of insecticide-resistance status of *Anopheles gambiae* sensu lato in urban areas in southwestern Ghana. *Journal of Vector Ecology, 44*(1), 60–70. https://doi.org/10.1111/jvec.12331
7. Midega, J. T., Mbogo, C. M., & Mwangangi, J. (2022). Ecological drivers of mosquito species diversity and their public health implications in an urban landscape. *Parasites & Vectors, 15*, Article 287. https://doi.org/10.1186/s13071-022-05370-z
8. Palmer, J. R. B., Oltra, A., Collantes, F., Delgado, J. A., Lucientes, J., Delacour, S., Bengoa, M., & Bartumeus, F. (2017). Citizen science provides a reliable and scalable tool to track disease-carrying mosquitoes. *Nature Communications, 8*, Article 916. https://doi.org/10.1038/s41467-017-00914-9
9. Powell, J. R., & Tabachnick, W. J. (2021). History of domestication and spread of *Aedes aegypti*: A review. In S. M. Carlson & D. W. Severson (Eds.), *Memórias do Instituto Oswaldo Cruz* (Vol. 108, pp. 11–17). Fundação Oswaldo Cruz. https://doi.org/10.1590/0074-0276130395
10. Rattanarithikul, R., Harrison, B. A., Panthusiri, P., & Coleman, R. E. (2005). *Illustrated keys to the mosquitoes of Thailand*. U.S. National Center for Infectious Diseases.
11. Ryan, S. J., Carlson, C. J., Mordecai, E. A., & Johnson, L. R. (2020). Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. *PLOS Neglected Tropical Diseases, 13*(3), e0007213. https://doi.org/10.1371/journal.pntd.0007213
12. Tiwari, A., Kumar, A., & Rawat, S. (2020). Impact of climate change on vector-borne diseases: A review. *Journal of Communicable Diseases, 52*(2), 1–12. https://doi.org/10.24321/0019.5138.202010
13. World Health Organization. (2021). *Global vector control response 2017–2030: An integrated approach for the control of vector-borne diseases*. https://www.who.int/publications/i/item/9789240012789
14. Bowman, L. R., Donegan, S., & McCall, P. J. (2016). Is Dengue Vector Control Deficient in Effectiveness or Evidence?: Systematic Review and Meta-analysis. PLoS neglected tropical diseases, 10(3), e0004551. https://doi.org/10.1371/journal.pntd.0004551

15. Indriani, C., Tantowijoyo, W., Rancès, E., Andari, B., Prabowo, E., Yusdi, D., Ansari, M. R., Wardana, D. S., Supriyati, E., Nurhayati, I., Ernesia, I., Setyawan, S., Fitriana, I., Arguni, E., Amelia, Y., Ahmad, R. A., Jewell, N. P., Dufault, S. M., Ryan, P. A., Green, B. R., … Utarini, A. (2020). Reduced dengue incidence following deployments of Wolbachia-infected Aedes aegypti in Yogyakarta, Indonesia: a quasi-experimental trial using controlled interrupted time series analysis. Gates open research, 4, 50. https://doi.org/10.12688/gatesopenres.13122.1
16. Kraemer, M. U., Reiner Jr, R. C., Brady, O. J., Messina, J. P., Gilbert, M., Pigott, D. M., ... & Hay, S. I. (2019). Past and future spread of the arbovirus vectors Aedes aegypti and Aedes albopictus. Nature Microbiology, 4(5), 854–863https://doi.org/10.1038/s41564-019-0376-y
17. Kummer, A. G., & Wilke, A. B. (2024). Comparing the effectiveness of adulticide application interventions on mitigating local transmission of the dengue virus. Journal of Pest Science, 1–13.10.1007/s10340-024-01787-w
18. Li, Y., Kamara, F., Zhou, G., Puthiyakunnon, S., Li, C., Liu, Y., Zhou, Y., Yao, L., Yan, G., & Chen, X.-G. (2014, November 13). Urbanization increases Aedes albopictus larval habitats and accelerates mosquito development and survivorship. PLOS Neglected Tropical Diseases, 8(11), e3301. https://doi.org/10.1371/journal.pntd.0003301
19. Souza-Neto, J. A., Powell, J. R., & Bonizzoni, M. (2019). Aedes aegypti vector competence studies: A review. Infection, genetics and evolution : journal of molecular epidemiology and evolutionary genetics in infectious diseases, 67, 191–209. https://doi.org/10.1016/j.meegid.2018.11.009
20. Zahouli, J. B. Z., Koudou, B. G., Müller, P., Malone, D., Tano, Y., & Utzinger, J. (2017, July 13). Urbanization is a main driver for the larval ecology of Aedes mosquitoes in arbovirus-endemic settings in south-eastern Côte d'Ivoire. PLOS Neglected Tropical Diseases, 11(7), e0005751. https://doi.org/10.1371/journal.pntd.0005751