



RESEARCH ARTICLE

Preliminary case study of vertical distribution and trap efficiency of *Aedes* (Diptera: Culicidae) mosquitoes in urban multi-storey buildings in Selangor, Malaysia

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ABSTRACT

The increasing prevalence of high-rise residential developments in dengue-endemic regions has created new challenges for understanding the distribution and surveillance of *Aedes* mosquitoes. This study investigated the vertical distribution of *Aedes* mosquitoes and evaluated the effectiveness of two modified low-cost sticky trap designs in a high-rise residential complex in Hulu Langat, Selangor, Malaysia. A total of 108 sticky traps comprising small and large trap designs were deployed across multiple floor levels in two residential blocks over four sampling rounds. Adult mosquitoes were identified morphologically, and trap performance was assessed using sticky trap indices and Generalized Estimating Equations (GEE) analysis. *Aedes aegypti* was the dominant species captured throughout the study, particularly in Block A, whereas *Ae. albopictus* was more frequently detected in Block B. Adult *Aedes* mosquitoes were recorded from lower parking levels to the highest residential floors, demonstrating extensive vertical distribution within the building environment. Large sticky traps consistently outperformed small traps, recording higher sticky trap indices, greater mosquito captures, and all mixed-species detections. Negative-binomial GEE indicated that floor level and trap size were significant predictors of *Ae. aegypti* abundance, while binary logistic regression showed that the probability of *Ae. aegypti* detection also increased with floor level and was substantially higher in large traps. These findings demonstrate that *Aedes* mosquitoes are capable of occupying a wide vertical range in high-rise residential buildings and highlight the value of low-cost sticky traps as practical surveillance tools. The study provides important ecological insights into urban mosquito distribution and supports the development of scalable surveillance strategies for dengue vector management in increasingly vertical urban landscapes.

Keywords: *Aedes*; surveillance; vertical distribution; trap efficiency; Malaysia.

INTRODUCTION

Dengue fever is a global health issue transmitted by the bite of female *Aedes* mosquitoes carrying dengue virus (DENV), a single-stranded RNA virus with four major serotypes (DENV-1 to DENV-4) that causes dengue fever. Two species of *Aedes* mosquitoes have been identified as the main vectors of the disease, namely *Aedes aegypti* and *Aedes albopictus*. The *Ae. aegypti* species acts as the primary vector while *Ae. albopictus* acts as the secondary vector. Both species are commonly found in tropical and subtropical climates, especially in urban and semi-urban areas that provide suitable environments for mosquito breeding (World Health Organization, 2025). Tropical and subtropical climates typically have high rainfall, temperature and humidity, which in turn create optimal conditions for breeding and increase the lifespan of vectors (Abd Majid *et al.*, 2021; Alias *et al.*, 2025).

Rapid urbanization, particularly the construction of high-rise residential buildings, has created a complex urban ecology that has the potential to accelerate the breeding and spread of *Aedes* mosquitoes (Dom *et al.*, 2026; Woods & Randle, 2025). This situation also poses new challenges to dengue vector surveillance and control efforts. Conventionally, vector surveillance strategies have focused on ground-level habitats and easily identifiable breeding sites, such as discarded containers, used tires and drainage systems. This approach implicitly assumes that vertical spread of *Aedes* mosquitoes is limited and spatially dominant at lower levels. However, recent evidence suggests that *Aedes* mosquitoes can spread effectively across multiple floor levels in high-rise buildings, and their presence at higher levels may have important implications for vector control strategies and public health, especially in dengue-endemic areas such as Malaysia. Over the past five decades, the urbanization rate in Malaysia has increased significantly from 28.4%

in 1970 to approximately 79% in 2024, with an urban population growth rate of approximately 4% per year (World Bank, 2023).

Selangor is one of the areas experiencing rapid urban development, including the increase in high-rise residential construction due to land constraints (Malaysia Gazette, 2018). A vector surveillance study conducted in several high-rise residential buildings in Kuala Lumpur and Selangor showed that both *Ae. aegypti* and *Ae. albopictus* species can be found from the ground floor to the upper floors of the buildings. The ovitrap index obtained also showed a wide vertical distribution range, indicating the continuous presence of vectors across the vertical profile of residential buildings. This finding is in line with observations in several other urban environments in Malaysia, including Kuala Lumpur, Selangor and Johor (Lau *et al.*, 2013; Lau *et al.*, 2015; Roslan *et al.*, 2022), where *Aedes* mosquito abundance was found to be higher at lower levels but could still be detected at significant heights, up to 21 storeys of buildings (Ab Hamid *et al.*, 2020). This situation indicates the need to refine vector surveillance strategies that consider the vertical spread of mosquitoes in high-density urban environments.

Sticky traps have been widely used in surveillance studies and vector control efforts. Unlike conventional ovitraps that focus on detecting mosquito eggs and larvae, sticky traps focus directly on adult mosquitoes, thus allowing for a more accurate assessment of the distribution of mosquito populations in an area. This approach can also reduce the bias caused by the skip-oviposition habit of *Aedes* mosquitoes, which is the behaviour of laying eggs in multiple locations to reduce competition between larvae (Reinbold-Wasson & Reiskind, 2021). In addition, the use of adult traps has the potential to help reduce adult mosquito population density, thus reducing the risk of virus transmission (Achee *et al.*, 2015; Smith *et al.*, 2012). The present study provides a preliminary assessment of adult *Aedes* occurrence across vertical levels within a single contemporary high-rise residential complex while simultaneously comparing two low-cost modified sticky trap configurations under paired sampling conditions.

To address this, the present study aimed to investigate the vertical distribution of adult *Aedes* mosquitoes within a high-rise residential environment, and evaluate the operational performance of two modified low-cost sticky trap designs for adult mosquito surveillance in the Hulu Langat district, Selangor, one of the areas that consistently records high dengue incidence. It was hypothesized that *Aedes* mosquitoes would still be detectable at higher floors of residential buildings, although their abundance would decrease with increasing building height. Furthermore, smaller sticky trap designs were expected to demonstrate higher capture efficiency compared to larger designs, due to their operational characteristics and their ability to effectively attract and retain adult mosquitoes within confined environmental spaces.

MATERIALS AND METHODS

Research area

The study was conducted at Residensi Rimbun (Canopy Hill), Kajang 2, located in Hulu Langat district, Selangor, Malaysia (2.958129200841876 N, 101.79537436838639 E). This high-rise residential complex was completed in 2022 and consists of two blocks (Block A and Block B), where each block comprised 27 numbered levels, with the basement through Level 5 used primarily for parking, level 6 containing shared recreational facilities, levels 7 to 26 comprising residential floors and level 27 consisting predominantly of rooftop/common outdoor areas. The site was selected due to its epidemiological relevance, as the residential area had previously been identified as a dengue hotspot for three consecutive weeks in 2024. Residensi Rimbun is adjacent to Kajang railway station and is located approximately 10 minutes from The National University of Malaysia and Bandar Baru Bangi, and about 20 minutes from Putrajaya city centre. As shown in Figure 1, the surrounding environment is characterised by rapid urban development, including several newly constructed high-rise residential complexes and ongoing construction projects in the



Figure 1. Geographic location of Residensi Rimbun (Canopy Hill) within Hulu Langat district, Selangor, Malaysia, showing the study site in relation to surrounding urban areas. Map source: OpenStreetMap.

immediate vicinity. These urbanisation dynamics potentially create favourable conditions for *Aedes* mosquito breeding and dispersal. Within the building structure, the basement level up to the fifth floor is designated for multi-storey parking facilities. The sixth floor contains shared recreational facilities including a swimming pool and gymnasium. Residential units occupy floors 7 to 26, while the 27th floor consists of rooftop areas used for outdoor activities. The site was considered suitable for this preliminary investigation due to the absence of previous entomological surveillance within a 200 m radius of the residence. Furthermore, Hulu Langat district has consistently reported one of the highest dengue case burdens in Selangor.

Trap design

Two types of modified sticky ovitraps were used in this study. The trap design was adapted from previously described models developed by (Roslan *et al.*, 2022), with minor modifications introduced to optimise trap functionality and affordability for community-based application. Each trap consisted of two containers: an outer black container that served as the water reservoir and an inner container fitted with adhesive surfaces for capturing adult mosquitoes attempting to oviposit. The inner container was modified by removing its base and lining the inner walls with commercially available insect sticky paper. This design allowed adult mosquitoes attracted to the infusion to enter the trap and become immobilised on the adhesive surface during oviposition attempts. The sticky papers used in the traps were inexpensive, widely available online, and safe to handle, making the trap design suitable for potential household-level deployment. Two trap sizes were tested in the study. The small trap had an outer container capacity of approximately 250 ml, while the large trap had a capacity of approximately 650 ml. Both trap types were filled with hay infusion prepared by fermenting dried grass in tap water for about a week. The infusion was used to simulate natural organic breeding conditions and enhance the attractiveness of the traps to gravid *Aedes* females seeking oviposition sites. Detailed specifications of each trap type are provided in Figure 2 and Table 1.

Placement of traps

A total of 108 traps were deployed during each sampling round across the selected high-rise residential buildings. At each floor level, two traps were installed, consisting of one large sticky trap (650 mL) and one small sticky trap (250 mL). The paired trap design allowed a direct comparison of the trapping performance between the two trap types under similar environmental conditions while minimising micro-habitat variability within the same floor level. The traps were placed at approximately 1-2 m from each other, typically near lift lobby areas or communal corridors that experience frequent human movement. The selection of placement is due to the protection from

direct rainfall, relatively shaded, and less exposed to strong wind currents, creating environmental conditions that are favourable for gravid female mosquitoes seeking oviposition sites. Previous entomological observations indicate that *Aedes* mosquitoes prefer dimly lit and protected environments when selecting breeding or oviposition habitats, making these semi-enclosed building spaces suitable for trap placement.

Sampling was conducted over four rounds between April and May 2025. During each round, all traps were left in place for approximately 3-5 days before being collected for laboratory examination. After each sampling period, the sticky substrates containing trapped mosquitoes were retrieved and transported to the laboratory for species identification. As for the entire study period, the total sampling effort consisted of 432 trap deployments (4 sampling rounds × 108 traps per round). This level of sampling effort is comparable to several urban entomological surveillance studies that utilise oviposition or sticky traps to monitor *Aedes* populations in residential environments. The use of paired traps

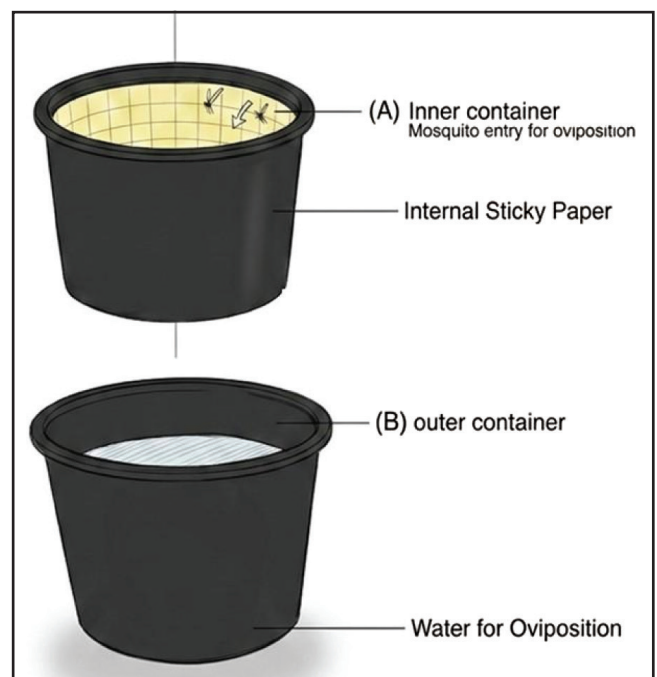


Figure 2. Schematic illustration of the modified sticky ovitrap design used in this study. The inner container (A) was modified by removing its base and lining the inner walls with adhesive paper to capture adult mosquitoes attempting to oviposit, while the outer container (B) contained hay infusion to attract gravid *Aedes* females.

Table 1. Physical characteristics of modified sticky ovitraps

Trap	Description
Small	Physical appearance: - Outer container: Black with an approximate size of 250ml (diameter 6.1 cm and height 9 cm). - Inner container: Transparent container with an approximate size of 180 ml (diameter 5.5 cm and height 7.2 cm). The inner wall has been glued with sticky paper. Price per trap: Approximate RM 1.99 / USD 0.50 Volume of hay infusion: 70 ml
Large	Physical appearance: - Outer container: Black with an estimated size of 650 ml (diameter 9.6 cm and height 9 cm). - Inner container: Black with an estimated size of 350ml (diameter 9 cm and height 5.7 cm). The inner wall of the container has been attached with sticky paper. Price per trap: Approximate RM 0.70 / USD 0.20 Volume of hay infusion: 300 ml



Figure 3. Trap placement within the residential complex: (a) traps installed in the multi-storey parking area, (b) traps positioned near elevator and staircase access points commonly used by residents, (c) a large sticky trap deployed at the study site prior to inspection after five days of sampling.

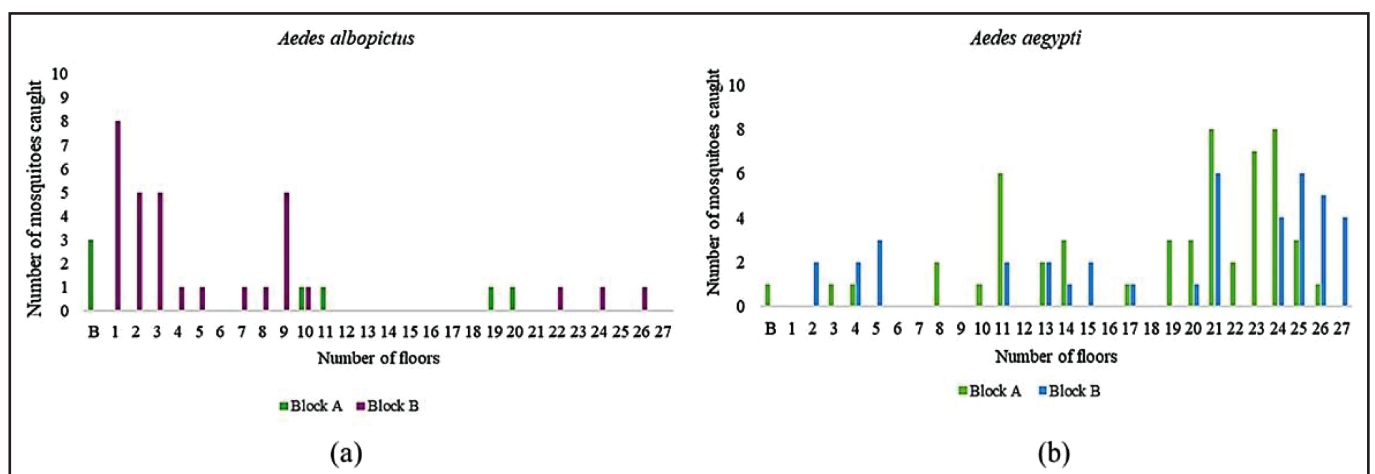


Figure 4. Vertical distribution of *Aedes* mosquitoes detected across different floor levels of the residential house.

across multiple floors allowed the study to assess both the vertical distribution of *Aedes* mosquitoes and the relative trapping efficiency of the two trap designs within the same structural environment, consistent with the methodology adopted (Roslan et al., 2022, 2024).

Identification of species

After each sampling period, sticky traps containing captured insects were transported to the laboratory for morphological identification. Adult mosquitoes adhered to the sticky surface were carefully examined using a stereomicroscope. Species identification was conducted using standard pictorial identification keys for *Aedes* mosquitoes.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corp., Armonk, NY, USA). Descriptive statistics were initially used to summarise mosquito abundance, trap positivity, and species composition according to floor level, residential block, and trap type. Generalized estimating equations (GEE) were used to account for the repeated measurements obtained from the same traps across the four sampling occasions. Species-specific analyses were conducted separately for adult *Aedes aegypti* and *Aedes albopictus*, with mosquito count as the dependent variable. A negative binomial distribution with a log-link function was specified to account for the overdispersal count nature of the data. Trap ID was specified as the subject effect, while sampling occasion was defined as the within-subject effect to account for the correlation among repeated observations from the same trap.

An exchangeable working correlation structure was used, assuming a common correlation among repeated observations within the same trap. Floor level was entered as a continuous covariate, whereas block and trap size were included as categorical factors. Sampling occasion was additionally included in the final model to account for temporal variation among sampling rounds. Two GEE models were fitted for each species. Model 1 included floor level, residential block, and trap size, whereas Model 2 additionally included sampling occasion to account for temporal variation across the four sampling rounds. The associations were expressed as regression coefficients (β), incidence rate ratios (IRRs), and corresponding 95% Wald confidence intervals (CIs). Model fit was compared using the quasi-likelihood under the independence model criterion (QIC) and the corrected QIC (QICC).

Ethical considerations

This study was approved by the National Institutes of Health Malaysia and registered under the National Medical Research Registry (NMRR ID: NMRR ID-24-02787-24Z).

RESULTS

Adult *Aedes* composition and trap performance

A total of 432 sticky traps was deployed across all floors in Blocks A and B throughout four sampling rounds conducted between April and May 2025. Both trap types successfully captured adult *Aedes* mosquitoes, confirming the suitability of the modified sticky ovitrap design for detecting *Aedes* presence in high-rise residential environments. Overall, the relative abundance of species differed between residential blocks. In block A, *Ae. aegypti* clearly dominated the captures, whereas block B showed a more balanced composition between *Ae. aegypti* and *Ae. albopictus*. The trapping results also revealed occasional mixed species captures within a single trap, indicating that both species utilised similar oviposition sites within the residential environment.

Analysis of Trap Performance

The trapping performance of the two sticky trap designs varied between residential blocks, as presented in Table 2. In Block A, large traps recorded a higher number of positive traps ($n = 23$) and a greater sticky trap index (21.3%) compared with small traps ($n = 7$; 6.48%). A similar pattern was observed in Block B, where large traps achieved a sticky trap index of 27.78% ($n = 30$ positive traps), substantially exceeding that of small traps (10.19%; $n = 11$ positive traps). Mixed-species captures of *Ae. aegypti* and *Ae. albopictus* were detected exclusively in large traps in both blocks. Species composition also differed between residential blocks, with *Ae. aegypti* dominating captures in Block A, whereas both species were detected in relatively comparable numbers in Block B. Overall, the results indicate that large sticky traps were more effective in detecting adult *Aedes* mosquitoes under the study conditions.

In the Table 3, the mosquito abundance varied across sampling occasions. For *Ae. aegypti*, mean counts were highest during Sampling 2 (0.33 mosquitoes per trap), followed by Sampling 1 (0.28), Sampling 3 (0.19) and Sampling 4 (0.05). Zero observations accounted for 15.7–17.6% of traps during the first two sampling rounds and declined to 4.6% in Sampling 4. For *Ae. albopictus*, no individuals were detected during Sampling 1, whereas mean counts were 0.07, 0.19 and 0.06 during Sampling 2, 3 and 4, respectively.

Generalized estimating equation analysis

Table 4 and 5 presents the Generalized Estimating Equations analysis used to account for repeated measurements obtained from the same trap across the four sampling occasions. For *Ae. aegypti*, Model 1 (Table 4) showed that floor level was positively associated with mosquito abundance ($\beta = 0.087$, IRR = 1.091, 95% CI: 1.048–1.136,

Table 2. Species composition and trapping performance of sticky traps in each residential block

Block	Type of Traps	Number of positive traps	Sticky Trap Index (%)	Single <i>Aedes</i>				Mixed <i>Aedes</i> species	
				<i>Ae. aegypti</i> only		<i>Ae. albopictus</i> only		Total mosquitoes caught, n (%)	Mean / species positive trap $\pm$ SE
				Total mosquitoes caught, n (%)	Mean / species positive trap $\pm$ SE	Total mosquitoes caught, n (%)	Mean / species positive trap $\pm$ SE		
A	Small	7/108	6.48	13 (92.9)	2.16 $\pm$ 0.83	1 (7.1)	0.14 $\pm$ –	–	–
	Large	23/108	21.30	32 (80.8)	1.89 $\pm$ 0.31	1 (2.2)	1.00 $\pm$ –	8 (17.8)	2.67 $\pm$ 0.47
B	Small	11/108	10.19	10 (52.6)	1.67 $\pm$ 0.33	9 (47.4)	1.80 $\pm$ 0.37	–	–
	Large	30/108	27.78	28 (52.8)	1.47 $\pm$ 1.42	15 (28.3)	1.88 $\pm$ 0.58	10 (18.9)	3.33 $\pm$ 0.94

Mean adults per positive trap was calculated using traps in which the respective species was detected; SE was calculated from the corresponding species-specific trap-level counts. Percentages represent the proportion of total mosquitoes captured within each trap type and block.

Table 3. Descriptive distribution of *Aedes* mosquito counts across sampling periods

Species	Sampling	Trap Observations	Mean Count	Minimum	Median	Maximum	Zero Observations (%)
<i>Ae. aegypti</i>	1	108	0.28	0.00	0.00	4.00	17.6
	2	108	0.33	0.00	0.00	6.00	15.7
	3	108	0.19	0.00	0.00	3.00	13.0
	4	108	0.05	0.00	0.00	1.00	4.6
<i>Ae. albopictus</i>	1	108	0.00	0.00	0.00	0.00	0.0
	2	108	0.07	0.00	0.00	2.00	6.5
	3	108	0.19	0.00	0.00	5.00	10.2
	4	108	0.06	0.00	0.00	5.00	1.9

Table 4. Generalized estimating equation (GEE) analysis of factors associated with *Ae. aegypti* abundance

Predictor	Model 1			Model 2		
	β	IRR (95% CI)	p-value	β	IRR (95% CI)	p-value
Floor level	0.087	1.091 (1.048–1.136)	<0.001	0.091	1.095 (1.052–1.140)	<0.001
Block A vs B	0.231	1.260 (0.712–2.231)	0.428	0.201	1.223 (0.692–2.159)	0.489
Large vs Small Trap	1.150	3.158 (1.554–6.416)	0.001	1.173	3.232 (1.613–6.469)	0.001
Sampling 1 vs 4	–	–	–	1.820	6.171 (2.418–15.751)	<0.001
Sampling 2 vs 4	–	–	–	2.063	7.872 (2.740–22.615)	<0.001
Sampling 3 vs 4	–	–	–	1.424	4.153 (1.672–10.315)	0.002

IRR = incidence rate ratio; CI = confidence interval; β = regression coefficient. Reference categories were Block B, small trap, and Sampling 4. Floor level was entered as a continuous variable.

Table 5. Generalized estimating equation (GEE) analysis of factors associated with *Ae. albopictus* abundance

Predictor	Model 1			Model 2		
	β	IRR (95% CI)	p-value	β	IRR (95% CI)	p-value
Floor level	-0.132	0.876 (0.814–0.943)	<0.001	-0.123	0.884 (0.824–0.947)	0.001
Block A vs B	-1.983	0.138 (0.044–0.428)	0.001	-1.976	0.139 (0.045–0.426)	0.001
Large vs Small Trap	0.935	2.568 (0.960–6.769)	0.060	0.975	2.651 (0.991–7.099)	0.052
Sampling 1 vs 4	–	–	–	NE*	NE*	–
Sampling 2 vs 4	–	–	–	0.337	1.401 (0.215–9.126)	0.724
Sampling 3 vs 4	–	–	–	1.218	3.381 (0.576–19.857)	0.177

IRR = incidence rate ratio; CI = confidence interval; β = regression coefficient. Reference categories were Block B, small trap, and Sampling 4. Floor level was entered as a continuous variable. NE, parameter not estimable because all observations for *Ae. albopictus* at Sampling 1 had zero counts, resulting in singularity of the Hessian matrix.

$p < 0.001$), indicating an approximately 9.1% increase in expected mosquito abundance for each one-floor increase. Trap size was also significantly associated with abundance, with large traps recording higher expected counts than small traps ($\beta = 1.150$, IRR = 3.158, 95% CI: 1.554–6.416, $p = 0.001$). Residential block was not significantly associated with *Ae. aegypti* abundance ($\beta = 0.231$, IRR = 1.260, 95% CI: 0.712–2.231, $p = 0.428$).

After additionally adjusting for sampling occasion in Model 2 (Table 5), the associations with floor level and trap size remained significant. Floor level was positively associated with *Ae. aegypti* abundance ($\beta = 0.091$, IRR = 1.095, 95% CI: 1.052–1.140, $p < 0.001$), while large traps continued to show higher expected counts than small traps ($\beta = 1.173$, IRR = 3.232, 95% CI: 1.613–6.469, $p = 0.001$). Residential block remained non-significant ($\beta = 0.201$, IRR = 1.223, 95% CI: 0.692–2.159, $p = 0.489$). Sampling occasion was significantly associated with *Ae. aegypti* abundance, with higher counts observed in Sampling 1, 2 and 3 than in Sampling 4 (IRR = 6.171, 7.872 and 4.153, respectively; all $p \leq 0.002$).

Model selection and goodness-of-fit assessment

Two negative binomial GEE models were evaluated for each species. Based on Table 6, Model 1 included floor level, block and trap size, whereas Model 2 additionally incorporated sampling occasion. For *Ae. aegypti*, Model 2 showed lower QIC (1424.486) and QICC (242.346) than Model 1 (QIC = 1504.481; QICC = 261.134). Similarly, for *Ae. albopictus*, Model 2 produced lower QIC (597.790) and QICC (118.436) compared with Model 1 (QIC = 669.790; QICC = 136.715). Therefore, Model 2 was selected because incorporation of sampling occasion improved model fit based on lower QIC and QICC values.

DISCUSSION

This preliminary study investigated the vertical distribution of adult *Aedes* mosquitoes and evaluated the operational performance of low-cost modified sticky traps within a high-rise residential environment in Selangor, Malaysia. Mean ambient temperatures during the study period ranged from 33.9–34.1°C, which falls within

Table 6. Comparison of negative binomial GEE model specifications based on QIC and QICC

Species	Model	Predictors	QIC	QICC
<i>Ae. aegypti</i>	Model 1	Floor level, block, trap size	1504.481	261.134
	Model 2	Model 1 + sampling occasion	1424.486	242.346
<i>Ae. albopictus</i>	Model 1	Floor level, block, trap size	669.790	136.715
	Model 2	Model 1 + sampling occasion	597.790	118.436

QIC = quasi-likelihood under the independence model criterion, QICC = corrected QIC.

the optimal developmental and survival range reported for *Ae. aegypti* (Pekl'anská et al., 2025). Consequently, temperature was unlikely to have limited mosquito occurrence during the sampling period. The study site consisted of two L-shaped residential blocks with open-sided parking levels extending from the basement to Level 5, open-ended residential corridors, multiple balcony areas, and elevator lobbies that were frequently connected to residential corridors through open doors and windows. Although the present study did not directly evaluate mosquito dispersal mechanisms, these architectural characteristics may provide opportunities for passive or active movement of adult *Aedes* mosquitoes throughout the building. Adult mosquitoes were detected across multiple floor levels in both residential blocks, including upper residential floors, indicating that mosquito activity within modern high-rise environments is not restricted to lower levels alone. However, the observed distribution patterns were heterogeneous and did not demonstrate a uniform distribution pattern across all floor levels. The heterogeneous distribution pattern observed across different floor levels suggests that surveillance approaches relying solely on lower-floor sampling may underestimate mosquito presence within the building.

In the present study, floor level was positively associated with *Ae. aegypti* abundance after accounting for repeated measurements within traps. The association remained consistent after adjustment for sampling occasion, with the expected abundance increasing by approximately 9.5% per additional floor (IRR = 1.095, 95% CI: 1.052–1.140, $p < 0.001$). Similarly, the positivity analysis showed approximately 10% higher odds of detecting *Ae. aegypti* per additional floor (OR = 1.100, 95% CI: 1.036–1.167, $p = 0.002$). This observation looks contrary to the initial expectation that mosquito abundance would decline with increasing building height, as well as from several previous studies conducted in high-rise residential areas in Selangor (Ab Hamid et al., 2020; Lau et al., 2013; Wan-Norafikah et al., 2010) and studies from other countries including China (Jin et al., 2023), Taiwan (Liao et al., 2023), and Indonesia (Andriyani et al., 2023), where mosquito abundance generally decreased with increasing building height. The detection of *Ae. aegypti* at upper residential levels in the present study suggests that vertical distribution patterns may vary depending on local ecological conditions and human activity within the building environment (Jayathilake et al., 2015).

While *Ae. aegypti* abundance increased with increasing floor level, *Ae. albopictus* abundance decreased significantly with height. After adjustment for sampling occasion, each additional floor was associated with an approximately 11.6% reduction in the expected abundance of *Ae. albopictus* (IRR = 0.884, 95% CI: 0.824–0.947, $p = 0.001$). This species-specific pattern suggests that vertical distribution within high-rise environments may not be uniform across *Aedes* species and may reflect differences in ecological preferences, dispersal behaviour, or interactions with building-associated environmental conditions. However, because the present study did not measure floor-specific environmental variables or dispersal mechanisms, these explanations remain hypotheses requiring further investigation. Although the present study was preliminary in nature, it suggests that surveillance protocols based on limited floor sampling may not adequately capture the spatial

variability of mosquito populations within high-rise residential structures. In addition, the observed species-specific patterns indicate that vertical mosquito distribution in modern residential buildings may be more complex than previously assumed.

This study should be viewed as a preliminary investigation. Future studies should incorporate longitudinal sampling across multiple seasons and residential complexes, along with environmental variables such as temperature, humidity per floor, rainfall, occupancy density, and availability of breeding sites. Molecular screening for dengue virus and insecticide resistance markers will further improve understanding of the epidemiological significance of vertically dispersed *Aedes* populations. Nevertheless, based on the researchers' observations throughout the sampling, there are several possible factors that may have contributed to this distribution trend. First, the higher incidence of trap loss and damage at lower levels may have resulted in fewer mosquito detections in the area, thus introducing a potential bias in the observed distribution pattern. The residential complex includes a multi-level parking area extending from the basement to the 6th floor, which experiences frequent movement of residents and vehicles. Therefore, it is possible that traps placed at this location were inadvertently disturbed by residents or cleaning staff, which may have compromised the reliability of mosquito capture on the lower floors.

Moreover, the establishment of resident *Aedes* populations on higher floors is biologically plausible given the presence of domestic water containers, ornamental plants and semi-enclosed microhabitats observed on several higher housing levels, which may serve as suitable oviposition sites. This may allow mosquitoes to complete their life cycle on upper residential floors, including corridors and indoor home environments. This mechanism is consistent with previous studies showing that human behavior and building use patterns play an important role in shaping the three-dimensional distribution of mosquitoes in urban environments (Dom et al., 2026; Jin et al., 2023). Overall, these findings suggest that the occurrence of *Ae. aegypti* at upper residential levels is unlikely to be solely the result of incidental dispersal and warrants further investigation into the ecological and behavioural factors influencing mosquito distribution in high-rise residential environments.

Large traps showed substantially higher *Ae. aegypti* abundance than small traps, whereas the association for *Ae. albopictus* was weaker and did not reach conventional statistical significance. This improved performance may be attributed to the larger volume of hay infusion used as an attractant, which may enhance mosquito attraction. In addition, the larger trap provides a greater internal surface area and potentially more stable microhabitat conditions, which may prolong the attractiveness of the trap to gravid female mosquitoes. The cost of constructing a single trap was estimated to be less than RM 2.00 (approximately USD 0.50), indicating that the trap design has potential as a low-cost tool for mosquito monitoring at the household level. Similar findings have been reported in both tropical and temperate settings, where trap design, infusion volume, and microenvironmental conditions have been shown to influence the capture rates of adult *Aedes* mosquitoes (Böckmann et al., 2021; de Santos et al., 2012; Roslan et al., 2017). Despite the small difference in unit cost between the two trap sizes, the higher capture efficiency of the larger trap suggests a favourable

cost-effectiveness profile, particularly for surveillance purposes in high-rise environments where sampling logistics may be challenging.

Dengue outbreaks are often associated with environmental sanitation issues and may disproportionately affect densely populated or lower-income residential areas (Ali *et al.*, 2026). Therefore, the development of affordable and easy-to-use mosquito traps may help facilitate community participation in vector surveillance and control. Although adult mosquitoes were consistently captured throughout the sampling period, the present study does not provide direct evidence that the traps reduced mosquito populations within the study area. Nevertheless, previous intervention-based studies have demonstrated that the sustained use of sticky traps can contribute to local reductions in adult *Aedes* populations when deployed at sufficient density and integrated with other vector control strategies (de Santos *et al.*, 2012; Facchinelli *et al.*, 2007; Roslan *et al.*, 2017). Accordingly, the present findings should be interpreted primarily as evidence of surveillance effectiveness rather than direct vector control impact. The concept of introducing a simple trap that can be implemented by the community is consistent with recommendations by the World Health Organization for rapid vector surveillance and control, particularly during dengue outbreaks. In situations where dengue transmission occurs rapidly, community participation becomes an important component of comprehensive vector control efforts (World Health Organization, 2009).

At the same time, increasing evidence suggests that reliance solely on insecticide-based interventions may be insufficient due to the emergence of insecticide resistance among *Aedes* populations. Several studies have reported reduced effectiveness of ultra-low volume (ULV) spraying and other chemical control measures (Esu *et al.*, 2010; Selvarajoo *et al.*, 2020). For this reason, the deployment of low-cost sticky traps should be viewed as a complementary household-level intervention within an integrated vector management framework rather than as a replacement for source reduction activities. Nevertheless, successful implementation of community-based vector control tools requires a high level of public awareness and participation. Knowledge, Attitude and Practice (KAP) studies related to dengue prevention are therefore important in assessing the readiness of communities to adopt such interventions. Previous studies conducted in Malaysia (Samsudin *et al.*, 2025; Selvarajoo *et al.*, 2020) as well as in countries such as Thailand (Crowley *et al.*, 2025) and Brazil (Zhang *et al.*, 2023) have indicated that there is still room for improvement in public knowledge regarding dengue prevention and vector control. These findings highlight the importance of strengthening public health education to support community-based vector surveillance initiatives.

Several limitations should be acknowledged when interpreting the findings of this study. The study design was observational and did not include intervention-based comparisons before and after trap deployment. Future studies should therefore explore whether the consistent use of adult mosquito traps at the household level can contribute to measurable reductions in *Aedes* population density. Another potential concern is that improperly maintained traps may inadvertently become breeding sites if left unattended for extended periods. For this reason, the use of such traps should be accompanied by appropriate public health education and regular monitoring to ensure that they function solely as surveillance tools rather than potential mosquito habitats. Despite these limitations, the present study provides useful preliminary evidence regarding the vertical distribution of *Aedes* mosquitoes in a high-rise residential environment. By extending mosquito surveillance to upper residential levels, the study contributes baseline information that may inform future longitudinal and intervention-based research in increasingly vertical urban landscapes.

CONCLUSION

This preliminary study demonstrated that adult *Aedes* mosquitoes were distributed across multiple floor levels within a high-rise residential environment in Selangor, Malaysia. Both abundance-based and positivity-based regression models consistently indicated increasing *Ae. aegypti* occurrence with increasing floor level. In addition, larger modified sticky traps demonstrated substantially higher mosquito detection efficiency compared with smaller traps. These findings highlight the importance of vertically integrated mosquito surveillance strategies in high-density urban housing environments and support the potential utility of low-cost sticky traps for community-based *Aedes* monitoring programmes.

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Conflict of Interest

The authors declare that they have no competing interests.

REFERENCES

- Ab Hamid, N., Mohd Noor, S., Isa, N.R., Rodzay, R.M., Effendi, A.M.B., Hafisool, A.A., Azman, F.A., Abdullah, S.F., Zaman, M.K.K., Norsham, I. *et al.* (2020). Vertical infestation profile of *Aedes* in selected urban high-rise residences in Malaysia. *Tropical Medicine and Infectious Disease* 5: 114. <https://doi.org/10.3390/tropicalmed5030114>
- Abd Majid, N., Rainis, R., Sahani, M., Mohamed, A.F., Aziz, S.A.A.G. & Nazi, N.M. (2021). Spatial pattern of dengue cases: an analysis in Bangi District, Selangor, Malaysia. *Geospatial Health* 16: 178-182. <https://doi.org/10.4081/gh.2021.915>
- Achee, N.L., Gould, F., Perkins, T.A., Reiner Jr., R.C., Morrison, A.C., Ritchie, S.A., Gubler, D.J., Teyssou, R. & Scott, T.W. (2015). A critical assessment of vector control for dengue prevention. *PLOS Neglected Tropical Diseases* 9: e0003655. <https://doi.org/10.1371/journal.pntd.0003655>
- Ali, K., Putri, S.M.D., Parmasari, D.H., Ma'rufi, I. & Adyana, I.M.D.M. (2026). Spatio-temporal analysis of environmental and socioeconomic determinants of dengue incidence in East Java province: A generalized additive mixed model approach. *Next Research* 5, 101294. <https://doi.org/https://doi.org/10.1016/j.nexres.2025.101294>
- Alias, A., Harun, S.N., Feisal, N.A.S., Abd Razak, M.K., Noor, N.M. & Wee, H.B. (2025). Determinants of dengue prevalence: *Aedes* density and environmental factors in Johor, Malaysia. *Majalah Kesehatan Indonesia* 6: 43-56. <https://doi.org/10.47679/makein.2025233>
- Andriyani, V., Handoyo, W. & Sayono, S. (2023). Arboviral vectors dispersal and density in storey buildings: the association of light intensity and air temperature. *Annals of Parasitology* 68: 727-735. <https://doi.org/10.17420/ap6804.480>
- Böckmann, E., Pfaff, A., Michael, S. & Pflanz, M. (2021). Rapid and low-cost insect detection for analysing species trapped on yellow sticky traps. *Scientific Reports* 11: 10419. <https://doi.org/10.1038/s41598-021-89930-w>
- Crowley, J., Liu, B. & Jan, H. (2025). Assessing the knowledge, attitudes, and practices (KAP) of dengue in Thailand: a systematic review and meta-analysis. *Archives of Public Health* 83: 38. <https://doi.org/10.1186/s13690-025-01522-6>
- de Santos, E.M.M., de Melo-Santos, M.A.V., de Oliveira, C.M.F., Correia, J.C. & de Albuquerque, C.M.R. (2012). Evaluation of a sticky trap (*Aedes*TrAP), made from disposable plastic bottles, as a monitoring tool for *Aedes aegypti* populations. *Parasites & Vectors* 5: 195. <https://doi.org/10.1186/1756-3305-5-195>
- Dom, N.C., Hisyam, A.N.S., Saeman, M.N., Latib, N.A.A., Ramli, M.I., Fisal, Z.A.M., Yusoff, N.M., Osman, M.A., Dapari, R. & Salleh, S.A. (2026). Housing structure shapes dengue transmission dynamics in a rapidly urbanizing Malaysian district. *Scientific Reports* 16: 6840. <https://doi.org/10.1038/s41598-026-35904-9>

- Esu, E., Lenhart, A., Smith, L. & Horstick, O. (2010). Effectiveness of peridomestic space spraying with insecticide on dengue transmission; systematic review. *Tropical Medicine & International Health* **15**: 619-631. <https://doi.org/10.1111/j.1365-3156.2010.02489.x>
- Facchinelli, L., Valerio, L., Pombi, M., Reiter, P., Costantini, C. & Della Torre, A. (2007). Development of a novel sticky trap for container-breeding mosquitoes and evaluation of its sampling properties to monitor urban populations of *Aedes albopictus*. *Medical and Veterinary Entomology* **21**: 183-195. <https://doi.org/10.1111/j.1365-2915.2007.00680.x>
- Jayathilake, T.A.H., Wickramasinghe, M. & de Silva, B.G.D.N. (2015). Oviposition and vertical dispersal of *Aedes* mosquitoes in multiple storey buildings in Colombo district, Sri Lanka. *Journal of Vector Borne Diseases* **52**: 245-251. <https://doi.org/10.4103/0972-9062.166272>
- Jin, S., Fan, J., Cao, H., Zhang, Z., Leng, P. & Gao, Q. (2023). Vertical dispersal of *Aedes albopictus* within multi-story buildings in downtown Shanghai, China. *Parasites & Vectors* **16**: 176. <https://doi.org/10.1186/s13071-023-05732-1>
- Lau, K.W., Chen, C.D., Lee, H.L., Izzul, A.A., Asri-Isa, M., Zulfadli, M. & Sofian-Azirun, M. (2013). Vertical distribution of *Aedes* mosquitoes in multiple storey buildings in Selangor and Kuala Lumpur, Malaysia. *Tropical Biomedicine* **30**: 36-45.
- Lau, S.-M., Vythilingam, I., Doss, J., Sekaran, S., Chua, T., Wan Sulaiman, W., Chinna, K., Lim, Y.A.L. & Venugopalan, B. (2015). Surveillance of adult *Aedes* mosquitoes in Selangor, Malaysia. *Tropical Medicine & International Health* **20**: 1271-1280. <https://doi.org/10.1111/tmi.12555>
- Liao, J.-R., Tu, W.-C., Chiu, M.-C., Kuo, M.-H., Cheng, H.-C., Chan, C.-C. & Dai, S.-M. (2023). Joint influence of architectural and spatiotemporal factors on the presence of *Aedes aegypti* in urban environments. *Pest Management Science* **79**: 4367-4375. <https://doi.org/10.1002/ps.7634>
- Malaysia Gazette. (2018). Selangor tumpu bina rumah bertingkat kerana tanah terhad. <https://malaysiagazette.com/2018/08/20/selangor-tumpu-bina-rumah-bertingkat-kerana-tanah-terhad/>
- Pekl'anská, M., van Heerwaarden, B., Hoffmann, A.A., Nouzová, M., Síma, R. & Ross, P.A. (2025). Elevated developmental temperatures below the lethal limit reduce *Aedes aegypti* fertility. *Journal of Experimental Biology* **228**: JEB249803. <https://doi.org/10.1242/jeb.249803>
- Reinbold-Wasson, D.D. & Reiskind, M.H. (2021). Comparative skip-oviposition behavior among container breeding *Aedes* spp. Mosquitoes (Diptera: Culicidae). *Journal of Medical Entomology* **58**: 2091-2100. <https://doi.org/10.1093/jme/tjab084>
- Roslan, M.A., Ngui, R., Karim, M.-A.-A., Rosmini, U.S., Ong, P.S., Ahmad, M.A., Lim, Y.A.L. & Wan Sulaiman, W.Y. (2024). A study on *Wolbachia*-dengue-carrying *Aedes* mosquitoes (Diptera: Culicidae) focuses on the sustainability and frequency of *Wolbachia* in high-rise buildings in Selangor, Malaysia. *Applied Entomology and Zoology* **59**: 225-236. <https://doi.org/10.1007/s13355-024-00870-z>
- Roslan, M.A., Ngui, R., Vythilingam, I., Chan, K.F., Ong, P.S., Low, C.K., Muhammed, N.A. & Wan Sulaiman, W.Y. (2022). Surveillance of *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) in high-rise apartment buildings in Selangor, Malaysia. *International Journal of Tropical Insect Science* **42**: 1959-1969. <https://doi.org/10.1007/s42690-021-00725-y>
- Roslan, M.A., Ngui, R., Vythilingam, I. & Wan Sulaiman, W.Y. (2017). Evaluation of sticky traps for adult *Aedes* mosquitoes in Malaysia: a potential monitoring and surveillance tool for the efficacy of control strategies. *Journal of Vector Ecology* **42**: 298-307. <https://doi.org/10.1111/jvec.12270>
- Samsudin, N.A., Zaini, Z.-I.I., Siau, C.S. & Othman, H. (2025). Evaluating urban community knowledge, attitudes, and preventive actions (KAP) using the health belief model: insights from an ideation-informed interpretation of recurrent dengue outbreaks in Selangor, Malaysia. *PLOS Neglected Tropical Diseases* **19**: e0013545. <https://doi.org/10.1371/journal.pntd.0013545>
- Selvarajoo, S., Liew, J.W.K., Tan, W., Lim, X.Y., Refai, W.F., Zaki, R.A., Sethi, N., Wan Sulaiman, W.Y., Lim, Y.A.L., Vadivelu et al. (2020). Knowledge, attitude and practice on dengue prevention and dengue seroprevalence in a dengue hotspot in Malaysia: a cross-sectional study. *Scientific Reports* **10**: 9534. <https://doi.org/10.1038/s41598-020-66212-5>
- Smith, D.L., Battle, K.E., Hay, S.I., Barker, C.M., Scott, T.W. & McKenzie, F.E. (2012). Ross, Macdonald, and a theory for the dynamics and control of mosquito-transmitted pathogens. *PLoS Pathogens* **8**: e1002588. <https://doi.org/10.1371/journal.ppat.1002588>
- Wan-Norafikah, O., Nazni, W.A., Noramiza, S., Shafa'ar-Ko'ohar, S., Azirol-Hisham, A., Nor-Hafizah, R., Ghazali, S., Mohd-Hasrul, H., Azirun, M. et al. (2010). Vertical dispersal of *Aedes* (*Stegomyia*) spp. in high-rise apartments in Putrajaya, Malaysia. *Tropical Biomedicine* **27**: 662-667.
- Woods, O. & Randle, S. (2025). Ecological responsibility in the city: the surfaces and volumes of urban mosquito management. *Urban Geography* **46**: 2019-2041. <https://doi.org/10.1080/02723638.2025.2512068>
- World Bank. (2023). Urban population Malaysia. World Bank. <https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2024&locations=MY&start=1960&view=chart>
- World Health Organization. (2009). Dengue: Guidelines for diagnosis, treatment, prevention and control: new edition. <https://iris.who.int/items/a1007087-7515-4cd2-9cac-ab481a5ecd36>
- World Health Organization. (2025). Dengue. World Health Organization. <https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue>
- Zhang, Y., Zahreddine, M., Abreu, K., Dantas, M.A., Charland, K., Pierce, L., Ridde, V. & Zinszer, K. (2023). Knowledge, attitude and practice (KAP) and risk factors on dengue fever among children in Brazil, Fortaleza: a cross-sectional study. *PLOS Neglected Tropical Diseases* **17**: e0011110. <https://doi.org/10.1371/journal.pntd.0011110>