ORIGINAL ARTICLE

Study on the Distribution and Abundance of *Aedes aegypti* and *Aedes albopictus* in Different Environment Settings for High-Rise Buildings

Zuhainy Ahmad Zhaki[1,3], Nazri Che Dom[1,2], Ibrahim Ahmed Alhothily[1]

[1] Centre of Environmental Health and Safety, Faculty of Health Sciences, Universiti Teknologi MARA Selangor, Malaysia
[2] Integrated of Mosquito Research Group (I-MeRGe), Faculty of Health Sciences, Universiti Teknologi MARA, Selangor, Malaysia
[3] Vector Control Unit, Kuala Langat District Health Office, Ministry of Health, Kuala Langat, Selangor, Malaysia

ABSTRACT

Introduction: Vector surveillance in high-rise buildings is important to predict and monitor the presence of vectors regarding their abundance and distribution. In this study, the infestation profile of *Aedes aegypti* and *Aedes albopictus* species in different environmental settings were investigated. **Methods:** Four high-rise apartments in four different localities were selected for ovitrap surveillance. Fifty ovitraps were placed in semi indoor and outdoor settings. **Results:** A total of 507 (42.8%) from ovitraps showed the presence of the *Aedes* species larvae. Out of these, 170 (33.5%) of the positive ovitraps were those placed in semi indoor and 337 (66.5%) in outdoor. Of the total 16,613 *Aedes* larvae found, 4,130 (24.9%) were from semi indoor, and 12,483 (75.1%) from outdoor. In terms of distribution, *Ae. albopictus* was predominantly found in outdoor environments (POI=87.5%; MLT=36.45 larvae). *Ae. aegypti* was also found in outdoor environments (POI=14.89%; MLT=8.26 larvae). There was a significant difference in POI for both *Ae. aegypti* and *Ae. albopictus* in the two different environments but no significant difference was observed in MLT, indicating that the density of the *Aedes* species in both environments was well distributed. **Conclusion:** In this study, the patterns of *Aedes* habitat in high-rise apartments were observed. This study has shown an invasion and adaptation of *Aedes* mosquitoes into the ecosystems of high-rise buildings. It can be concluded that housing designs and the condition of the surrounding environment affects the infestation profile and the distribution of *Aedes* mosquitoes.

Keywords: *Aedes aegypti*, *Aedes albopictus*, High-rise buildings, Ovitrap surveillance

Corresponding Author:
Nazri Che Dom, PhD
Email: nazricd@uitm.edu.my
Tel: + 603-32584447

INTRODUCTION

Dengue fever is an urban viral disease. The virus is carried by female *Aedes* mosquitoes and can be transmitted to humans through the bites of these infected mosquitoes (1,2). The vector that causes dengue fever consists of two species of *Aedes* mosquitoes namely *Ae. albopictus* and *Ae. aegypti*. The abundance of these species is influenced by the preference and inherent behaviors in oviposition of these female mosquitoes, as well as biotic and abiotic factors (3). Environmental factors such as relative humidity, wind and temperature influence the occurrence and density of these species. Anthropogenic changes in the environment will influence the abundance and distribution of *Ae. aegypti* whilst *Ae. albopictus* will mainly be influenced by the presence of vegetation in the surrounding area (4). The main factor contributing in the epidemiology of the dengue fever disease is the behavior of mosquitoes within the field itself (3). A difference in pattern of habitat preference can be seen between these species as certain studies revealed a higher abundance of *Ae. aegypti* in indoor areas while *Ae. albopictus* shows a higher occurrence in outdoor areas (5,6,7).

Dengue cases have also been reported in high-rise buildings that offer places of residence in the form of flats, apartments or condominiums (1). Human activities and poorly-maintained sanitation in the surrounding area can trigger the breeding of mosquitoes. High-rise buildings designed with rain gutters that make cleaning almost impossible offer the best breeding conditions for mosquitoes as regions with improper drainage and piping systems show high potential in becoming *Aedes* habitats (1). Essentially, there are a lot of potential breeding spots in high-rise buildings, including the areas surrounding it. It is very difficult to control and monitor the prevalence of these mosquitoes as checking and cleaning activities in these areas are usually limited and

not thorough. *Aedes* larvae are usually found breeding in both natural and artificial containers and they do not necessarily breed independently; both species can be found simultaneously within the same breeding container (8,9). High-rise buildings offer the perfect ecosystem for *Aedes* mosquitoes to breed, providing them the potential to create shelter and resting areas, breeding sites, and the benefit of access to humans as their blood meals (8).
Thus, it is important to conduct a vector surveillance in high-rise buildings to predict the presence of these vectors, their changing density levels, the frequency of occurrence and any other epidemiological factors which relates to their vectorial capacity (10). It is important to have basic information on the density of these vectors, their abundance, as well as their distribution (10). Previous studies claim that ovitrap surveillance is a more efficient technique to measures the presence of *Aedes* vectors (9,11,12). This technique was used as a sampling method to determine the positive ovitrap index (POI) which serves as an indicator in evaluating the abundance and distribution of the *Aedes* population within the study area (3,9). This approach can also be used to assess the fluctuation rates of the *Aedes* population over an extended period of time, especially in epidemiology studies. In this study, ovitrap surveillance through a series of ovitraps activities was conducted to identify the *Aedes* profile for both *Ae. aegypti* and *Ae. albopictus* species in and around high-rise buildings apartments in Bandar Saujana Putra, Selangor. The outcome of this study may provide a minimum information required to assess the problem arises in high-rise buildings.

MATERIALS AND METHODS

Description of study sites

The ovitrap surveillance was conducted in selected high-rise apartments in four different localities; Pangsapuri Impian (PI), Pangsapuri Seri Saujana (PSS), BSP 21 (B21), and BSP Skypark (BSP). Fig. 1 shows the location of these high-rise apartments. All four localities are situated in Bandar Saujana Putra under Mukim Tanjung in Kuala Langat, Selangor. These four localities of high-rise apartments had been selected due to a series of dengue outbreak incidences that had been reported by the Vector Control Unit of the Kuala Langat Health Office from 2014 to 2018.

All localities were identified as sub-urban residential areas, where two of them are considered as low-cost apartments (PI and PSS) and the other two are serviced apartments (B21 and BSP). PI and PSS are located side to side. PI is a five storey low-cost apartment with eighteen blocks whereby each block consists of eighty houses and PSS is a low-cost apartment with five storey blocks consisting of ten blocks and each block has eighty units of houses. B21 consists of ten blocks of serviced apartments with eighteen and twenty-seven storey buildings while BSP is a serviced residence consisting

Figure 1: Sampling sites: Four different locality of high-rise apartment in Bandar Saujana Putra; (PI) Pangsapuri Impian (orange), (PSS) Pansgapuri Seri Saujana (blue), (B21) BSP 21 (green) and (BSP) BSP Skypark (yellow).

of two blocks of apartments with six hundred and eighty nine units of houses. Both PI and PSS have been in service for approximately eight years and the overall surroundings seem poorly-maintained with unmanaged trash disposal, untidy communal yards and an overgrowth of vegetation. The surrounding area appears unclean with piles of garbage randomly scattered at almost every floor. In contrast, the surrounding environment of B21 and BSP is well kept with planted trees, with the area looking cleaner and well maintained in terms of sanitation with proper waste management systems in place. However, certain areas in B21 was quite messy as it still under construction works progress in that area. A summary of the geographical and ecological description of each locality is as shown in Table I.

Study design

The study aims to evaluate the infestation profile of *Aedes* mosquitoes within selected high-rise buildings in Kuala Langat, Selangor. The profile of *Aedes* density was measured through data collected from conventional ovitrap surveillance. Ovitrapping was done to obtain a baseline data of the infestation profile. Therefore, the sampling was conducted on three independent visits of all localities between 3rd December 2018 to 4th March 2019 (14 weeks). The selected months were chosen due to high Dengue Fever cases reported during that period. In this study, the ovitrap was placed at places deemed as "semi indoor" and "outdoors". Semi indoors would refer to areas inside the building itself, namely areas covered by the roof of the building whilst outdoors refers to areas outside the building area, including the surrounding environment (3,4). The ovitrap containers were placed randomly near potential breeding spots in order to capture more accurate results.

Table I: Geographical and ecological description of each locality

Study sites (abbreviation)	Geographical Description	Physical Description	Ecological Description
Pangsapuri Impian (PI)	Located in SP4, Bandar Saujana Putra (2.955436, 101.583453)	-Low cost apartment consist of 18 blocks -Each block consists of 5 floors -Each block consists of 80 units of houses -Each unit of house consists of 3 rooms -The building is about 8 years	-Untidy yard, trash, abundant and overgrown vegetation -The environment is generally not clean and not well manage -There are many scatted garbage dump area on each floor
Pangsapuri Seri Saujana (PSS)	Located in SP4, Bandar Saujana Putra (2.954036, 101.583205)	-Low cost apartment consist of 10 blocks -Each block consists of 5 floors -Each block consists of 80 units of houses -Each unit of house consists of 3 rooms -The building is about 8 years	-Untidy yard, trash, abundant and overgrown vegetation -The environment is generally not clean and not well manage -There are many scatted garbage dump area on each floor
BSP 21 (B21)	Located in SP4, Bandar Saujana Putra (2.944184, 101.589295)	-Serviced apartment consists of 10 blocks -Each block consists of 18 to 27 storey apartment units -28 shop units -The building is about 1 year	- The environment is clean and well managed such as good waste management and sanitation. - However, certain area was quite messy as it is still under construction works progress in that area. -The surrounding area is planted with trees.
BSP Skypark (BSP)	Located in SP7, Bandar Saujana Putra (2.941659, 101.588121)	Serviced apartment consists of 2 blocks -689 apartment units, 32 shop units -The building is about 2 years	-The environment is clean and well managed such as good waste management and sanitation -The surrounding area is planted with trees.

Note:PI: Pangsapuri Impian, PSS: Pangsapuri Seri Saujana, B21: BSP 21, and BSP: BSP Skypark.

Other considerations taken is for them to be placed in areas with less physical and environmental interference (10,12) in order to reduce the risk of misplaced or malfunctioning ovitrap containers. The ovitraps were recovered after five days in their designated areas and were brought back to the laboratory for larvae species identification (10,13). At every locality, ovitrapping was done during three independent visits. For each visit, a total of a hundred ovitraps were placed. Fifty ovitraps were placed accordingly in semi indoors and outdoors settings respectively and was distributed randomly up to level five of the buildings. All collected ovitrap were labelled according to their location and prescribed localities (14). All larvae were identified according to their species by looking at specific criteria for each species. The numbers of larvae in each ovitrap were also recorded.

Data analysis

Positive ovitrap index (POI) and mean larvae per ovitrap (MLT) were calculated to assess the density of *Aedes* mosquito with regard to their distribution and abundance (14). The POI was determined by dividing the number of positive ovitraps with the number of recovered ovitraps during collection and multiplied by 100 to obtain a percentage. The MLT was determined by dividing the total number of larvae with the number of recovered ovitraps (14). The POI and MLT for both semi indoor and outdoor settings were then categorized to reflect information based on the two separate species. The analysis of the *Aedes* infestation profile based on the environment was then subjected to a non-parametric test (the Wilcoxon test) with the significance level of (p=0.05) in order to determine whether there exists a significant difference in the distribution of *Aedes* mosquitoes within different environments, namely the semi indoor and outdoor environments.

RESULTS

Infestation profile of Aedes mosquitoes in high-rise buildings.

Out of the total of 1,200 ovitraps that were deployed throughout the duration of the ovitrap surveillance, 1,185 (98.8%) were successfully recovered. A total of 507 (42.8%) traps showed the presence of *Aedes* (Stegomyia) species larvae; 170 (33.5%) positive traps were from semi indoor locations and 337 (66.5%) positive traps were from the outdoors. Out of the total of 16,613 *Aedes* larvae detected, 4,130 (24.9%) were from the semi indoor ovitraps, and 12,483 (75.1%) were from ovitraps recovered from the outdoors. The results and findings obtained from the surveillance and survey of the *Aedes* species in four high-rise apartments are tabulated in Table II and Table III. Both tables show the percentage of positive ovitrap index (POI) and mean larvae per trap (MLT) during the three independent visits of all four study sites. The results were also classified into semi indoor ovitraps and outdoor settings. In general, all localities exceeded the transmission threshold of 10%, with the highest percentage of POI observed during the 3rd visit in PI (POI=70.40%) whilst the lowest reading was observed during the 1st visit in BSP (POI=19.60%). It can be concluded that PI has a higher density of *Aedes* mosquitoes as compared to PSS, B21 and BSP. The highest POI observed for PSS is during the 3rd visit (POI=63%), and during the 2nd visit (POI=39%) for B21. Several factors were believe that contribute to this results are likely due to the presence of artificial breeding containers (e.g. tires, food container, plastic, can, bottle) that female adult mosquitoes can oviposit easily found in surrounding outdoor area. Based on observations during field surveillance, it can be suggested that the density of *Aedes* species could also be influenced by the size of the area, the population density, the type of apartment, the age of the building and the degree of cleanliness of each apartment.

Table II shows the positive ovitrap index (POI) of *Aedes* species for semi indoor and outdoor ovitrap setting. From the total number of positive ovitraps (n=507), (n=170) was recovered from semi indoor setting and (n=337) was recovered from outdoor settings. During the 3rd visit in PI and PSS, both recorded the highest POI at 44%. Meanwhile, for the outdoor setting, the POI during the 3rd visit in PI registered at 97.9% which shows that almost all ovitraps recovered tested positive for signs of breeding. Apart from that, the result was also classified into percentages of specific *Aedes* species (*Ae. albopictus* and *Ae. aegypti*) found within semi indoor and outdoor settings. The findings indicated that the percentage of *Ae. albopictus* found was higher when compared to *Ae. aegypti* for ovitraps placed in both settings. For semi indoor settings, the highest percentage registered based on *Aedes* species was 64.29% for *Ae. aegypti* in B21 during the 2nd visit and 90.91% for *Ae. albopictus* at PI during the 3rd visit. On the other hand, the highest percentage based on *Aedes* species in outdoor setting was 27.27% for *Ae. aegypti* in BSP during the 3rd visit and 92.11% for *Ae. albopictus* in PSS during the 2nd visit. The distribution of *Ae. albopictus* were higher outdoor could be influenced due the presence of stagnant water in several location and also from apartment surrounding, such as drainage system, walkways, roof structure and corridors of the apartment.

The hatching of the eggs into larvae enabled the identification of the larvae into both *Aedes* species, namely *Ae. aegypti* and *Ae. albopictus*. Overall, a total of 16,613 *Aedes* larvae were examined in this study; 4,130 were *Ae. Aegypti* larvae and 12,483 were *Ae. albopictus* larvae. This indicates that the *Ae. albopictus* population is almost four times higher than that of *Ae. aegypti*. The total number of *Ae. aegypti* (24.9%) larvae recorded was lower as compared to *Ae. albopictus* (75.1%), showing that the infestation of *Ae. albopictus* was high in this study area. Therefore, it can be concluded that *Ae. albopictus* is the dominant species as opposed to *Ae. aegypti* within this study area. This might be due to the preference of *Ae. albopictus* to rest outdoors and the outdoor design of these types of housing offer great breeding potential for this species. *Ae. albopictus* larvae were the highest recorded for all localities (PI=5,145 larvae, PSS=3,769 larvae, B21=1,836 larvae, and BSP=2,001 larvae). While there is not much difference in the number of each *Aedes* species in semi indoor spaces, there is a huge difference in number between *Ae. albopictus* larvae (80.95%) and *Ae. aegypti* larvae (19.05%) in an outdoor setting (Table III). It is also noteworthy that PI recorded the highest numbers of larvae from the two species out of all localities (PI=5,898 larvae, PSS=4,860

Table II: **Positive ovitrap index (POI) and percentage of PO for Aedes aegypti and Aedes albopictus in semi indoor and outdoor settings**

L	OP	RO	PO	POI (%)	Semi indoor									Outdoor								
					RO	PO	POI (%)	Ae. aegypti			Ae. albopictus			RO	PO	POI (%)	Ae. aegypti			Ae. albopictus		
								PO	%PO	POI	PO	%PO	POI				PO	%PO	POI	PO	%PO	POI
PI	1st visit 3/12/18	95	59	62.1	50	17	34	2	11.76	4	15	88.24	30	45	42	93.3	5	11.90	11.11	37	88.10	82.22
	2nd visit 17/12/18	100	51	51.0	50	19	38	6	31.58	12	13	68.42	26	50	32	64	5	15.63	10	27	84.37	54
	3rd visit 31/12/18	98	69	70.4	50	22	44	2	9.09	4	20	90.91	40	48	47	97.9	5	10.63	10.42	42	89.37	87.5
Average PI		**98**	**60**	**61.17**	**50**	**19**	**38.67**	**3**	**17.48**	**6.67**	**16**	**82.52**	**32**	**48**	**41**	**85.07**	**5**	**12.72**	**10.51**	**36**	**87.28**	**74.57**
PSS	1st visit 10/12/18	97	54	55.7	50	19	38	4	21.05	8	15	78.95	30	47	35	74.5	7	20	14.89	28	80	59.57
	2nd visit 24/12/18	99	43	43.4	50	5	10	2	40	4	3	60	6	49	38	77.6	3	7.89	6.12	35	92.11	71.43
	3rd visit 7/1/19	100	63	63.0	50	22	44	12	54.54	24	10	45.46	20	50	41	82	10	24.39	20	31	75.61	62
Average PSS		**99**	**53**	**54.03**	**50**	**15**	**30.67**	**6**	**38.53**	**4**	**9**	**61.47**	**19**	**49**	**38**	**78.03**	**7**	**17.43**	**13.67**	**31**	**82.57**	**64.33**
B21	1st visit 14/1/19	99	25	25.5	50	10	20	4	40	8	6	60	12	49	15	30.6	6	40	12.24	9	60	18.37
	2nd visit 28/1/19	100	39	39.0	50	14	28	9	64.29	18	5	35.71	10	50	25	50	7	28	14	18	72	36
	3rd visit 11/2/19	100	24	24.0	50	14	28	4	28.57	8	10	71.47	20	50	10	20	3	30	6	7	70	14
Average B21		**100**	**29**	**29.5**	**50**	**13**	**25.33**	**6**	**44.29**	**11.33**	**7**	**55.73**	**14**	**50**	**16**	**33.53**	**5**	**32.67**	**10.75**	**11**	**67.33**	**22.79**
BSP	1st visit 4/2/19	97	19	19.6	50	7	14	2	28.57	4	5	71.47	10	47	12	25.5	3	25	6.38	9	75	19.15
	2nd visit 18/2/19	100	27	27.0	50	9	18	3	33.33	6	6	66.67	12	50	18	36	4	22.22	8	14	77.78	28
	3rd visit 4/3/19	100	34	34.0	50	12	24	6	50	12	6	50	12	50	22	44	6	27.27	12	16	72.73	32
Average BSP		**99**	**27**	**26.87**	**50**	**9**	**18.67**	**3**	**37.3**	**7.33**	**6**	**62.71**	**11**	**49**	**18**	**35.17**	**4**	**28.83**	**8.79**	**14**	**75.17**	**26.38**
Total/ *Average		**1185**	**507**	***42.9**	**600**	**170**	***28.3**	**56**	***34.42**	***9.33**	**112**	***65.61**	***19**	**585**	**337**	***58**	**64**	***21.91**	***10.93**	**273**	***78.09**	***51.72**

Note: Abbreviation: L: Locality, OP: Ovitrap placement, NO: Total number of ovitrap, RO: Number of recovered ovitrap, PO: Number of positive ovitrap, POI: Positive ovitrap index

Table III: Mean larvae per ovitrap (MLT) for *Aedes aegypti* and *Aedes albopictus* in semi indoor and outdoor settings

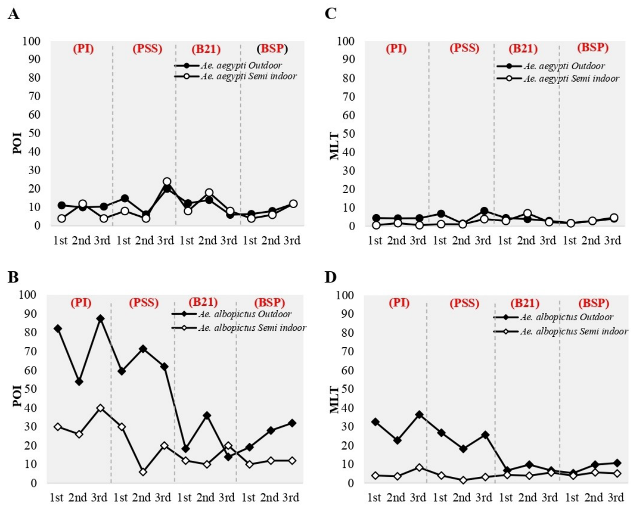
L	OP	TL	RO	PO	Semi Indoor								Outdoor							
					PO	RO	TL	MLT	Ae. aegypti		Ae. albopictus		PO	RO	TL	MLT	Ae. aegypti		Ae. albopictus	
									TL	MLT	TL	MLT					TL	MLT	TL	MLT
	1st visit	1891	95	59	17	50	226	4.52	27	0.54	199	3.98	42	45	1665	37.00	198	4.4	1467	32.6
PI	2nd visit	1609	100	51	19	50	262	5.24	83	1.66	179	3.58	32	50	1347	26.94	210	4.2	1137	22.74
	3rd visit	2398	98	69	22	50	441	8.82	27	0.54	414	8.28	47	48	1957	40.77	208	4.3	1749	36.45
Average PI		**1966**	**98**	**60**	**19**	**50**	**310**	**6.2**	**46**	**0.92**	**264**	**5.28**	**40**	**48**	**1656**	**34.9**	**205**	**4.3**	**1451**	**30.6**
	1st visit	1824	97	54	19	50	251	5.02	53	1.06	198	3.96	35	47	1573	33.64	314	6.68	1259	26.79
PSS	2nd visit	988	99	43	5	50	127	2.54	51	1.02	76	1.52	38	49	861	17.57	68	1.39	793	16.18
	3rd visit	2048	100	63	22	50	353	7.06	192	3.84	161	3.22	41	50	1695	33.90	413	8.26	1282	25.64
Average PSS		**1620**	**99**	**53**	**15**	**50**	**244**	**4.87**	**99**	**1.97**	**145**	**2.9**	**38**	**49**	**1376**	**28.37**	**265**	**5.44**	**1111**	**22.87**
	1st visit	896	99	25	10	50	357	7.14	143	2.86	214	4.28	15	49	539	11.00	216	4.41	323	6.59
B21	2nd visit	1223	100	39	14	50	544	11.08	347	6.98	197	3.94	25	50	679	13.58	190	3.8	489	9.78
	3rd visit	867	100	24	14	50	389	7.78	111	2.22	278	5.56	10	50	478	9.56	143	2.86	335	6.7
Average B21		**995**	**100**	**29**	**13**	**50**	**430**	**13.29**	**200**	**4.02**	**230**	**4.59**	**17**	**50**	**565**	**11.38**	**183**	**3.69**	**382**	**7.69**
	1st visit	600	97	19	7	50	272	5.44	78	1.56	194	3.88	12	47	328	6.98	81	1.72	247	5.26
BSP	2nd visit	1052	100	27	9	50	425	8.50	142	2.84	283	5.66	18	50	627	12.54	136	2.72	491	9.82
	3rd visit	1217	100	34	12	50	483	9.66	230	4.6	253	5.06	22	50	734	14.68	201	4.02	533	10.66
Average BSP		**956**	**99**	**27**	**10**	**50**	**393**	**7.87**	**159**	**3**	**243**	**4.87**	**17**	**49**	**563**	**11.4**	**139**	**2.82**	**424**	**8.58**
Total/ *Average		**16613**	**1185**	**507**	**170**	**600**	**4130**	***8.06**	**1484**	**2.48**	**2646**	**4.41**	**337**	**585**	**12483**	***22.44**	**2378**	**4.06**	**10105**	**17.44**

Note: Abbreviation: L: Locality, OP: Ovitrap placement, TL: Number of total larvae, RO: Number of recovered ovitrap, PO: Number of positive ovitrap, MLT: Mean larvae per trap.

larvae, B21=2,986 larvae, and BSP=2,869 larvae). These result shows that PI is the locality with the highest *Aedes* density as compared to the rest. The findings on distribution indicated that *Ae. albopictus* was found in higher numbers in both indoor and outdoor environment as compared to *Ae. aegypti* in all localities of these high-rise buildings and it seems to be the dominant species in the outdoor environment.

Comparisons of positive ovitrap index and mean larvae per ovitrap of *Aedes* species in semi indoor and outdoor setting

Fig. 2 represents the POI distribution of *Ae. aegypti* (A) and the POI of *Ae. albopictus* (B) in different environment settings separately. The presence of *Ae. aegypti* in semi indoor and outdoor environment was recorded in all localities from first to the last visit. The highest POI number was noted to be at PSS during the 3rd visit for both semi indoors (POI=24%) and outdoors (POI=20%). (Fig. 2A). Overall, the trend of distribution for *Ae. albopictus* was higher outdoors as compared to semi indoors. The highest number of this species registered for the outdoors was recorded during the 3rd visit at PI (POI=87.5%) and the peak number of the species registered for the semi indoor environment is also seen during the 3rd visit at PI (POI=40%) (Fig. 2B). The larvae density was expressed by the MLT, with the highest mean of *Ae. aegypti* per trap was recorded during the 2nd visit at B21 (MLT=6.98 larvae) in semi indoor environment and during the 3rd visit at PSS (MLT=8.26 larvae) in the outdoor environment. The lowest MLT for *Ae. aegypti* seen in semi indoor environment was recorded (MLT=0.54 larvae) during



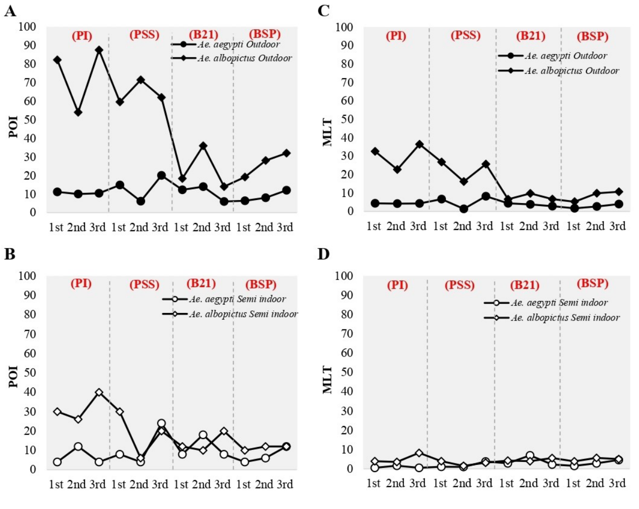
POI = Positive ovitrap index
(**A**) Distribution of *Ae. aegypti* POI per ovitrap in different environment setting
(**B**) Distribution of *Ae. albopictus* POI per ovitrap in different environment setting

MLT = Mean larvae per trap
(**C**) Distribution of *Ae. aegypti* MLT per ovitrap in different environment setting
(**D**) Distribution of *Ae. albopictus* MLT per ovitrap in different environment setting

Figure 2: Distribution of POI and MLT according to the *Aedes aegypti* and *Aedes albopictus* species in different environment. The histogram are devided into four section; (PI) Pangsapuri Impian, (PSS) Pangsapuri Seri Saujana, (B21) BSP 21 and (BSP) BSP Skypark.

the 1st and the 2nd visit in PI (Fig. 2C). The highest MLT of *Ae. albopictus* was recorded in PI during the 3rd visit (MLT=36.45 larvae) for the outdoors and (MLT=8.28 larvae) semi indoors (Fig. 2D).

Fig 2 focuses on comparison between the distribution of same *Aedes* species in different environmental setting which is semi indoor and outdoor separately. In contrast, Fig 3 focuses on the comparison between



POI = Positive ovitrap index
(A) Distribution of *Ae. aegypti* and *Ae. albopictus* in outdoor setting.
(B) Distribution of *Ae. aegypti* and *Ae. albopictus* POI in semi indoor setting

MLT = Mean larvae per trap
(C) Distribution of *Ae. aegypti* and *Ae. albopictus* MLT in outdoor setting.
(D) Distribution of *aegypti and Ae. albopictus* MLT in semi indoor setting

Figure 3: Distribution of POI and MLT of Aedes aegypti compared to those Aedes albopictus species in same environment. The histogram are devided into four section; (PI) Pangsapuri Impian, (PSS) Pansgapuri Seri Saujana, (B21) BSP 21 and (BSP) BSP Skypark.

the distribution of two different species (*Ae. aegypti* and *Ae. albopictus*) in the same environmental setting. The distribution between *Ae. aegypti* POI and the *Ae. albopictus* POI in the same environment is presented in Fig. 3A and B. A constant and high occurrence of *Ae. albopictus* can be seen in the outdoor environment as compared to *Ae. aegypti*. Both species had the lowest occurrence at the semi indoor setting. The MLT distribution of *Ae. aegypti* and *Ae. albopictus* show the same trends with the above for both species (Fig. 3C and D). *Ae. albopictus* recorded the highest POI in an outdoor environmental setting (POI=87.5%) during the the 3rd visit in PI, whilst *Ae. aegypti* exhibited its highest at POI=14.89% during the 1st visit in PSS. (Fig. 3A). For the semi indoor environmental setting, the same trend is seen as *Ae. albopictus* recorded the higher POI (POI=40%) during the 3rd visit in PI while *Ae. aegypti* with POI=24% during the 3rd visit in PSS (Fig. 3B). Overall, the trends distribution of *Ae. albopictus* was high as compared to *Ae. aegypti* in both semi indoor and outdoor environmental settings. The larvae density was expressed by the mean larvae per trap (MLT). MLT for *Ae. aegypti* was recorded lower as compared to MLT for *Ae. albopictus*. In the outdoor environmental setting, the highest MLT for *Ae. albopictus* was recorded during the 3rd visit in PI (MLT=36.45 larvae) whilst highest MLT for *Ae. aegypti* was recorded during the 3rd visit in PSS (MLT=8.26 larvae) (Fig. 3C). The highest MLT of *Ae. albopictus* in the semi indoor environment was recorded during the 3rd visit in PI (MLT=8.28 larvae) whilst the highest for *Ae. aegypti* was during the 2nd visit in B21 (MLT=6.98 larvae) (Fig. 3D).

Further analysis and comparison of the POI and MLT between the *Ae. aegypti* and *Ae. albopictus* species according to landscapes are shown in Table IV. There is a significant difference between *Ae. aegypti* and *Ae. albopictus* in both semi indoor and outdoor environments on POI but no significant difference is observable in MLT. The comparison in POI and MLT of the *Ae. aegypti* and the *Ae. albopictus* POI in the same environmental setting also showed a significant difference but no significant difference is notable in the MLT values, which in turn indicates that the density of *Aedes* species in both environmental settings was high and distributed well. The POI of *Ae. albopictus* was noticeably higher than POI of *Ae. albopictus* in both environments.

DISCUSSION

The result of this study showed the distribution and infestation profile of dengue vectors in high-rise buildings based on semi indoor and outdoor environment. Overall, the distribution of *Ae. albopictus* is higher in outdoor environments as opposed to semi indoor environments. These findings could be influenced by the presence of stagnant water in several locations, including certain aspects of the apartment surroundings, such as the drainage system, the walkways, the roof structure and corridors of the apartments. Apart from that, the balance of a suitable ecosystem, plus the abundance of vegetation and shady areas surrounding it are contributing factors to there being a high number of potential breeding sites in high-rise buildings. This study highlighted that *Ae. albopictus* is the dominant species in the outdoor environment of high-rise buildings as compared to *Ae. aegypti*. The total number of *Ae. aegypti* (24.9%) recorded is lower compared to *Ae. albopictus* (75.1%), showing that the infestation of *Ae. albopictus* was higher in this study area. This might be due to the preference of *Ae. albopictus* to rest/nest outdoors and this type of housing design offers numerous breeding areas within its outdoor environment. Such results corroborate those recorded by Dom et al, (5) which reported that *Ae. albopictus* is the prime *Aedes* species in multi-story buildings in Subang Jaya, Selangor. Also, Chen et al, and Wan et al, (6,7) reported a high density of *Ae. albopictus* in high-rise buildings. The previous authors agree that the scattered vegetation found in their study settings could contribute to the findings. This present study found that *Ae. albopictus* is well-known as an outdoor breeder that prefers breeding in shady areas surrounded by vegetation, as suggested by Norzahira et al, (14) which explains why the higher density of the species in this study region. Therefore, the local assessment of the infestation profile of *Aedes* can help to improve the management of the environment as well as assist in the implementation of other control measures.

Contrary to the current finding, a previous study by Wan et al. (9) reported that *Ae. aegypti* has dominance over *Ae. albopictus* in high-rise buildings in Putrajaya. The author concludes that the *Aedes* species can predominantly be found in or around buildings as it depends on humans for a blood meal. Meanwhile, the current result suggests that the high density of *Ae. albopictus* observed in the study area due to balance and suitable ecosystem that provide human as blood meals, shady resting area indoor and outdoor (14) as adult mosquitoes preferred to rest in areas with high human density. A lot of positive breeding conditions in the area around high-rise buildings make it one of the reasons why *Ae. albopictus* were in higher prevalence than *Ae. aegypti*.

Monitoring the distribution and abundance of *Aedes* mosquitoes is important in order to predict dengue epidemics in high active settings for *Aedes* (14). Changes in climate, availability of vegetation cover, and the environment of the breeding site are factors that affect mosquito distribution and abundance (16). Studying the preferred habitat of *Aedes* species helps to understand the complexities of dengue outbreaks and to determine the potential breeding patterns or habits of different mosquito species (17). The findings of this study indicates that surrounding environments do have an effect on the choice of breeding habitat of *Aedes* mosquitoes. *Ae. albopictus* is capable of breeding in a wide range of container types including in a building structure (18). In general, the control activities in this housing type were mostly focused on areas outside the buildings due to the abundance of neglected containers which encourage the breeding of *Aedes* mosquitoes (19, 20). The implication of the result showed that *Aedes* mosquitoes had invaded and adapted to the human ecosystem thus promoting dengue transmission, if there are no control measures taken in this type of buildings. In relation to this problem, appropriate control measures should be designed to tackle the issue of the potential breeding sites in high-rise buildings, thus reducing the transmission of dengue.

Vector control and surveillance; community participation and enforcement are the three major components in dengue control programs. The best solution so far is to have an effective surveillance system and to encourage inter-agency collaboration while also including the public in order to ensure a successful elimination of entire possible breeding sites. Integrated vector management (IVM) and other relevant approaches that act as vector control to this type of residential area should be developed by local authorities to remove or eliminate any potential breeding sites in order to prevent dengue transmission. Common adult mosquito control using chemical-based thermal fogging to kill adult mosquitoes can cause resistance in vector control with regular application over long periods of time. Therefore, it is suggested do control at larval stage which is essentially larvicide using biological insecticides such as Bacillus thuringiensis israelensis (Bti). These kinds of insecticides can be used regularly and will not cause resistance in vectors or cause any harm to the environment. There are various options of application for Bti treatment, making it more suitable for use in housing areas. An example would be by using ultra low volume (ULV) spraying, mist blower, pressure sprayer or by direct application to the targeted sites.

CONCLUSION

The key to effectively controlling DF outbreak in high-rise buildings is to understand the infestation characteristics of *Aedes* mosquitoes. Some patterns of *Aedes* habitat in high-rise buildings were observed from this present study. This study has shown an invasion and adaptation of *Aedes* mosquitoes to high-rise building ecosystems. It can be concluded that, housing design and surrounding environment conditions affect the infestation profile and distribution of *Aedes* mosquito in this area. Thus, the long-term solution to the dengue scourge is maintenance and cleanliness.

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