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Vertical distribution of *Aedes* mosquitoes in multiple storey buildings in Selangor and Kuala Lumpur, Malaysia

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Abstract. The aim of the present study was to determine the vertical distribution and abundance of *Aedes* mosquitoes in multiple storey buildings in Selangor and Kuala Lumpur, Malaysia. Ovitrap surveillance was conducted for 4 continuous weeks in multiple storey buildings in 4 residential areas located in Selangor [Kg. Baiduri (KB)] and Kuala Lumpur [Student Hostel of University of Malaya (UM), Kg. Kerinchi (KK) and Hang Tuah (HT)]. The results implied that *Aedes* mosquitoes could be found from ground floor to highest floor of multiple storey buildings and data from different elevation did not show significant difference. Ovitrap index for UM, KB, HT and KK ranged from 0 – 29.17%, 0 – 55.56%, 8.33 – 83.33% and 0 – 91.17% respectively. *Aedes aegypti* and *Aedes albopictus* were found breeding in HT, KK and KB; while only *Ae. albopictus* was obtained from UM. The results indicate that the invasion of *Aedes* mosquitoes in high-rise apartments could facilitate the transmission of dengue virus and new approaches to vector control in this type of residential area should be developed.

INTRODUCTION

Mosquito-borne diseases such as dengue haemorrhagic fever and dengue fever (DF) are the most important arthropod-borne viral diseases of public health in Malaysia. In the year 2011, a total of 19,884 DF cases were reported with 36 deaths in Malaysia (Ministry of Health Malaysia, 2011). *Aedes aegypti* and *Aedes albopictus* are the two major vectors involved in these infections. (Lam, 1993; Chen *et al.*, 2005a).

Aedes aegypti is a domestic mosquito in urban areas exclusively breed in artificial containers such as earthen jars and plastic containers which contain relatively clear water near human dwellings (Hasanuddin *et al.*, 1997), while *Ae. albopictus* was reported breeding in artificial containers and natural containers near human dwellings (Hawley, 1988). Both species are adapted to urban and suburban areas (Chen *et al.*, 2006). The close association between human and *Aedes* mosquitoes has provided the mosquitoes with breeding sites, shelter, and blood meals, which can increase the risk of dengue transmission.

Ovitrap surveillance is the commonest sampling method to monitor *Aedes* mosquitoes populations (Service, 1992; Cheng *et al.*, 1982). According to Lee (1992b), ovitrap surveillance has been shown to be a more effective and sensitive technique especially when the *Aedes* infestation rates were low.

Many studies had been done in Malaysia to determine the population and abundance of *Aedes* mosquitoes (Lee, 1992a, 1992b; Chen *et al.*, 2005b, 2006; Rozilawati *et al.*, 2007; Wan-Norafikah *et al.*, 2009). However, little information is available on the distribution of *Aedes* mosquitoes at different level of high-rise buildings. A preliminary study on the vertical dispersal of *Aedes* population in high-rise apartments was conducted by Wan-Norafikah *et al.* (2010) in Putrajaya. Their study indicated the possibility of lower *Aedes* population to be found at higher level of high-rise apartments. However, their study was conducted in high-rise apartments with 10 levels in one study site only.

The present study was conducted in high-rise apartments located in 4 selected urban residential areas in Kuala Lumpur and Selangor. This study provides more comprehensive information regarding the vertical distribution and abundance of *Aedes* mosquitoes in high-rise apartments in Kuala Lumpur and Selangor, Malaysia. Furthermore, this work explains the extent of *Ae. aegypti* and *Ae. albopictus* co-habitation in vertically distributed breeding sites.

MATERIALS AND METHODS

Description of study sites

Ovitrap surveillance was conducted in high-rise apartments located in 4 residential areas namely, Kg. Baiduri (KB), Student Hostel's University of Malaya (UM), Kg. Kerinchi (KK) and Hang Tuah (HT). The geographical and ecological description of the study sites are given in Table 1.

Table 1. Geographical and ecological description of study sites

Study site	Geographical Description	Physical Description	Ecological Description
12th Student College, University of Malaya (UM)	• 3°07'N, 101°35'E • Located in Kuala Lumpur	• The building consists of 9 floors. • 34 units of rooms each floor. • Each floor is about 3.0 meter in height. • The building is about 10 years old.	• High vegetation in the study site. • Tree and shrubs planted around the student college. • The environment is generally clean and well managed.
Vista Angkasa Apartment, Kampung Kerinchi (KK)	• 3°06'N, 101°39'E • Located in Kuala Lumpur near the border of Selangor state.	• The building consists of 15 floors. • 10 units of houses each floor. • Level height is 3.0 meter. • The building is about 15 years old.	• Scattered vegetation around the apartment. • Proper waste manage-ment and drainage system.
Sri Sarawak Apartment, Hang Tuah (HT)	• 3°08'N, 101°42'E • Located in the city center of Kuala Lumpur.	• The building consists of 16 floors. • 16 units of houses each floor. • Level height is 3.0 meter. • The building is more than 20 years old.	• Sparse vegetation and artificial pond around the apartment. • Poor waste manage-ment and sanitation. • Some of the households have ornamental plants placed around the corridor in front of their house.
Impian Baiduri Apartment, Kampung Baiduri (KB)	• 3°05'N, 101°37'E • Located in Selangor.	• The building consists of 16 floors. • 20 units of houses each floor. • Each floor is about 3.0 meter in height. • The building is about 3 years old.	• Scatted vegetation around the building. • Proper waste management and drainage system.

Ovitrap surveillance

Ovitrap as described by Lee (1992a) was used in this study. The ovitrap consists of 300 ml plastic container with straight, slightly tapered sides. The opening measures 7.8 cm in diameter, the base diameter is 6.5 cm, and the container is 9.0 cm in height. The outer wall of the container is coated with a layer of black oil paint. An oviposition paddle made from hardboard with measurement of 10.0 cm (Length) x 2.5 cm (Width) x 0.3 cm (Thick) was placed diagonally into each ovitrap which was filled with tap water to the level of 5.5 cm.

Ovitraps were placed randomly in each floor of the apartment from ground level to highest level. Ovitraps were placed in not less than 10% of the rooms/houses in each level of the apartments in all study sites. Ovitraps were placed indoor along corridor near stairways, nearby the ornamental plants and under the shoe rack. In this study, "indoors" refers to the interior of the apartments (Wan-Norafikah *et al.*, 2010).

All ovitraps were collected after 5 days and replaced with fresh ovitraps and paddles. Four continuous weekly ovitrap surveillance was conducted in UM and HT, except for KK and KB, where only three collections were made.

Identification of larvae

The collected ovitraps were brought back to laboratory and the contents were poured into plastic container, together with the paddle. Fresh water was added into the container and a small piece (10 mm) of fresh beef liver was added as larval food. The larvae were allowed to hatch and colonize in the laboratory for another 9 days. The hatched larvae were subsequently counted and identified at 3rd instar. The larval numbers were recorded individually for each positive ovitrap.

Data analysis

All data obtained from this study was analysed as follow:

1. Ovitrap Index (OI), the percentage of positive ovitrap against the total number of ovitraps recovered from each site.
2. Mean number of *Ae. aegypti* and/or *Ae.* albopictus larvae per recovered ovitrap.

All levels of statistical significance were determined at $P \leq 0.05$ by using the statistical programme, student t-test and one-way ANOVA (SPSS v 11.5). The linear regression analysis (SPSS v 11.5) was conducted to determine the correlation coefficient between OI and level of high-rise apartment. The associations between mean number of larvae per ovitrap and level of high-rise apartment were assessed by spearman rank-order correlation (SPSS v 11.5).

RESULTS

Table 2 shows the ovitrp index (OI) and the mean number of larvae per ovitrap of *Ae. aegypti* and *Ae. albopictus* obtained from ovitrap surveillance conducted in 4 high-rise apartments located in Kuala Lumpur and Selangor. The highest ovitrap index was obtained from Hang Tuah (HT) (45.08%), followed by Kg. Kerinchi (KK) (37.48%), Kg. Baiduri (KB) (21.43%) and University of Malaya (UM) (11.43%). There was significant difference between OI obtained from apartments in all study sites ($P < 0.05$). The mean number of *Ae. aegypti* larvae per ovitrap obtained form HT (9.26 ± 0.93) was significant higher than KK (6.20 ± 3.21) and KB (2.64 ± 0.42). There was no *Ae. aegypti* reported in UM. On the other hand, UM (1.50 ± 0.57) had higher mean number of *Ae. albopictus* larvae per ovitrap than KK (0.55 ± 0.27), HT (0.30 ± 0.11) and KB (0.24 ± 0.13), but this was not significantly different ($P > 0.05$).

Ovitrap index of each level in all apartments. *Aedes* were found breeding from ground floor to highest floor in KK and HT. Two out of 9 floors and 6 out of 16 floors in apartments located in UM and KB showed no *Aedes* breeding, respectively. However, there was no significant difference of OI in each floor within the apartment ($P > 0.05$) (Figure 1). The OI obtained from KK, HT, KB and UM ranged from 0–91.67%, 8.33–83.33%, 0–55.56% and 0–29.17%, respectively.

The mean numbers of larvae per ovitrap of *Ae. aegypti* and *Ae. albopictus* obtained from ovitrap surveillance in each floor in 4 high-rise apartments are shown in

Table 2. Comparative ovitrap index (mean ± S.E.) and larval number (mean ± S.E.) per ovitrap obtained from four high-rise apartments located in Kuala Lumpur and Selangor, Malaysia

Site	No. of Ovitrap Surveillance conducted	No. of collected ovitrap	Ovitrap Index (%)	Collected Larvae						*Ae. aegypti* : *Ae. albopictus* in the population	Comparison of the mean number larvae per ovitrap of *Ae. aegypti* & *Ae. albopictus* within the study site
				Aedes aegypti			*Aedes albopictus*				
				Total number of larvae	%	Mean number of larvae per ovitrap	Total number of larvae	%	Mean number of larvae per ovitrap		
University of Malaya (UM)	4	104 / 108	11.43 ± 1.26	0	0	0.00 ± 0.00	150	100	1.50 ± 0.57	0 : 1	T = -2.632 P = 0.039
Kg. Kerinchi (KK)	3	175 / 180	37.48 ± 15.80	1054	91.41	6.20 ± 1.21	99	8.59	0.55 ± 0.27	11.27 : 1	T = 4.557 P = 0.010
Hang Tuah (HT)	4	145 / 192	45.08 ± 3.80	1347	96.77	9.26 ± 0.93	45	3.23	0.30 ± 0.11	30.87 : 1	T = 9.568 P = 0.000
Kg. Baiduri (KB)	3	108 / 144	21.43 ± 9.43	276	91.39	2.64 ± 0.42	26	8.61	0.24 ± 0.13	11.00 : 1	T = 5.459 P = 0.005
One way ANOVA			F = 3.98 *P* = 0.042			F = 34.43 *P* = 0.000			F = 2.84 *P* = 0.092		

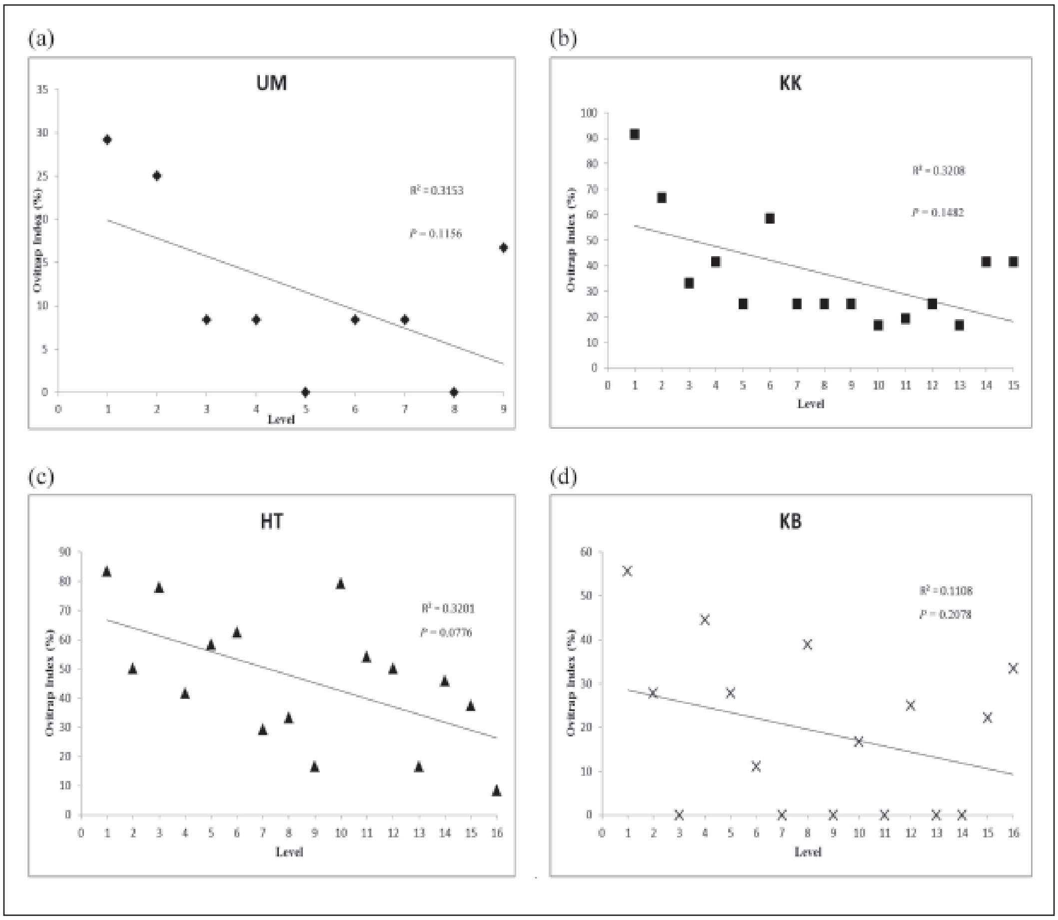

Figure 1. Relationship between ovitrap index (%) and level of four high-rise apartments located in (a) University of Malaya (UM), (b) Kg. Kerinchi (KK), (c) Hang Tuah (HT), and (d) Kg. Baiduri (KB)

Table 3. These data indicated that *Ae. aegypti* was significantly dominant than *Ae. albopictus* for HT, KK and KB ($P < 0.05$) by 11 to 31 times. In contrast, *Ae. albopictus* was the only principal dengue vector found in UM. The mean number larvae per ovitrap of *Ae. albopictus* obtained from UM, KB, KK and HT ranged from 0–9.63, 0–2.89, 0–2.75 and 0–2.13, respectively. On the other hand, mean number larvae per ovitrap of *Ae. aegypti* obtained from KK, HT and KB ranged from 0.33–34.50, 0.42–28.00 and 0–11.67, respectively. Generally, *Ae. aegypti* was found breeding up to the highest floor (16th floor, 45.1–48.0 m), while *Ae. albopictus* was only up to fourteenth floor (39.1–42.0 m). Although the highest mean number of larvae were found in first level of each apartment, there was no significant correlation between the mean number of *Aedes* larvae collected with the height of the apartment (UM: $r = -0.471$, $P = 0.193$; KK: $r = -0.036$, $P = 0.893$; KB: $r = -0.293$, $P = 0.263$) except HT ($r = -0.682$, $P = 0.004$), indicating that *Aedes* could be found breeding in every level of the apartment and not restricted by the height of the apartment.

Table 4 shows the percentage and ratio of *Ae. aegypti* and *Ae. albopictus* mixed breeding in ovitrap surveillance conducted in high-rise apartments in Kuala Lumpur and Selangor. The percentage of mixed breeding in HT, KB and KK accounted for 10.77%, 15.00% and 26.56% from the total collected ovitraps, respectively. In addition, the number of *Ae. aegypti* larvae found in mixed breeding ovitrap were 1.50–3.44 folds more that *Ae. albopictus*.

Table 3. Mean number of larvae (mean ± S.E.) per ovitrap obtained from four high-rise apartments located in Kuala Lumpur and Selangor, Malaysia

		University of Malaya (UM), Kuala Lumpur			Kg Kerinchi (KK), Kuala Lumpur			Hang Tuah (HT), Kuala Lumpur			Kg. Baiduri (KB), Selangor		
Level	Height (m)	*Ae. aegypti*	*Ae. albopictus*	*Aedes* sp*	*Ae. aegypti*	*Ae. albopictus*	*Aedes* sp*	*Ae. aegypti*	*Ae. albopictus*	*Aedes* sp*	*Ae. aegypti*	*Ae. albopictus*	*Aedes* sp*
1	0.0–3.0	0.00 ± 0.00	9.63 ± 5.96	9.63 ± 5.96	34.50 ± 1.62	2.75 ± 1.52	37.25 ± 1.91	28.00 ± 10.40	0.00 ± 0.00	28.00 ± 10.40	11.67 ± 6.17	2.89 ± 1.85	14.56 ± 7.98
2	3.1–6.0	0.00 ± 0.00	1.25 ± 1.25	1.25 ± 1.25	3.33 ± 1.12	1.50 ± 1.25	4.83 ± 1.45	16.58 ± 10.72	0.17 ± 0.17	16.75 ± 10.75	2.83 ± 2.59	0.00 ± 0.00	2.83 ± 2.59
3	6.1–9.0	0.00 ± 0.00	0.17 ± 0.17	0.17 ± 0.17	4.25 ± 2.92	0.75 ± 0.75	5.00 ± 2.51	22.39 ± 10.86	0.00 ± 0.00	22.39 ± 10.86	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
4	9.1–12.0	0.00 ± 0.00	1.67 ± 1.67	1.67 ± 1.67	7.83 ± 4.04	0.42 ± 0.42	8.25 ± 4.05	6.25 ± 2.59	0.00 ± 0.00	6.25 ± 2.59	0.78 ± 0.40	0.00 ± 0.00	0.78 ± 0.40
5	12.1–15.0	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.08 ± 0.74	0.00 ± 0.00	1.08 ± 0.74	14.92 ± 6.34	1.00 ± 0.59	15.92 ± 5.94	4.00 ± 3.51	0.00 ± 0.00	4.00 ± 3.51
6	15.1–18.0	0.00 ± 0.00	0.33 ± 0.33	0.33 ± 0.33	3.08 ± 1.50	0.83 ± 0.51	3.91 ± 1.23	12.08 ± 5.82	0.33 ± 0.33	12.41 ± 6.13	0.56 ± 0.56	0.00 ± 0.00	0.56 ± 0.56
7	18.1–21.0	0.00 ± 0.00	0.42 ± 0.42	0.42 ± 0.42	2.92 ± 2.55	0.08 ± 0.08	3.00 ± 2.63	3.50 ± 1.75	0.88 ± 0.88	4.38 ± 2.17	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
8	21.1–24.0	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.67 ± 0.67	0.00 ± 0.00	0.67 ± 0.67	6.09 ± 3.57	0.25 ± 0.25	6.34 ± 3.75	5.56 ± 1.37	0.00 ± 0.00	5.56 ± 1.37
9	24.1–27.0	0.00 ± 0.00	1.09 ± 0.88	1.09 ± 0.88	7.33 ± 7.33	0.00 ± 0.00	7.33 ± 7.33	1.25 ± 1.25	0.00 ± 0.00	1.25 ± 1.25	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
10	27.1–30.0				1.50 ± 1.50	0.00 ± 0.00	1.50 ± 1.50	14.33 ± 7.76	2.13 ± 2.13	16.46 ± 6.82	4.84 ± 4.84	0.00 ± 0.00	4.84 ± 4.84
11	30.1–33.0				5.72 ± 4.53	0.00 ± 0.00	5.72 ± 4.53	5.84 ± 1.38	0.00 ± 0.00	5.84 ± 1.38	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
12	33.1–36.0				4.67 ± 3.33	0.67 ± 0.55	5.33 ± 2.96	4.00 ± 2.45	0.00 ± 0.00	4.00 ± 2.45	0.75 ± 0.75	0.00 ± 0.00	0.75 ± 0.75
13	36.1–39.0				0.33 ± 0.33	0.00 ± 0.00	0.33 ± 0.33	6.84 ± 4.27	0.00 ± 0.00	6.84 ± 4.27	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
14	39.1–42.0				5.42 ± 3.34	1.25 ± 0.66	6.67 ± 2.68	13.42 ± 7.45	0.00 ± 0.00	13.42 ± 7.45	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
15	42.1–45.0				12.75 ± 1.13	0.00 ± 0.00	12.75 ± 1.13	0.63 ± 0.38	0.00 ± 0.00	0.63 ± 0.38	2.56 ± 2.56	0.00 ± 0.00	2.56 ± 2.56
16	45.1–48.0							0.42 ± 0.42	0.00 ± 0.00	0.42 ± 0.42	0.67 ± 0.67	0.00 ± 0.00	0.67 ± 0.67
Spearman's rank correlation		–	–	r = -0.471 P = 0.193	–	–	r = -0.036 P = 0.893	–	–	r = -0.682 P = 0.004	–	–	r = -0.293 P = 0.263

*Mean number of *Ae. aegypti* and *Ae. albopictus* larvae per ovitrap

Table 4. Mixed breeding of *Ae. aegypti* and *Ae. albopictus*

Study site	No. of collected ovitrap	Total no. positive ovitrap	No. Ovitrap with mixed breeding of *Ae. aegypti* and *Ae. albopictus*	Percentage of positive ovitrap (%)			Ratio of *Ae. aegypti* : *Ae. albopictus* in mixed breeding
				Ae. aegypti only	*Ae. albopictus* only	Mixed breeding of *Ae. aegypti* and *Ae. albopictus*	
University of Malaya, Kuala Lumpur	104	12	0	0.00	100.00	0.00	Nil
Kg. Kerinchi, Kuala Lumur	175	64	17	70.31	3.13	26.56	3.44 : 1.00
Hang Tuah, Kuala Lumpur	145	65	7	87.69	1.54	10.77	1.91 : 1.00
Kg. Baiduri, Selangor	108	20	3	85.00	0.00	15.00	1.50 : 1.00

DISCUSSION

According to Tham (2000), ovitrap surveillance is to obtain information on *Aedes* larval densities in terms of time and space to determine the major breeding sources as well as early forecast of impending outbreaks of dengue. Among the four high-rise apartments, HT showed significantly higher OI than other apartment buildings. However, the mean numbers of larvae in each ovitrap were less than 10. This phenomenon may due to avoidance of "superoviposion" by female as reported by Chadee *et al.* (1988). In other words, the female mosquitoes preferred to lay eggs in ovitraps having small number of pre-existing eggs to ensure the survival of their progeny (Williams *et al.*, 2008). There was significant difference between the number of larvae per ovitrap of *Ae. aegypti* and *Ae. albopictus* obtained from 4 apartments (Table 2). *Aedes aegypti* population was dominant in KB, KK and HT and these results were similarly reported by Lee (1992a) and Chen *et al.* (2006) in *Aedes* surveillance conducted in Selangor state.

Aedes aegypti is a domestic mosquito in urban areas and in Malaysia breeds exclusively in artificial containers such as jars, drums and small discarded containers containing relatively clean water near human dwellings (Hasanuddin *et al.*, 1997). The present results suggest that the high-rise apartment creates a complete ecosystem and provide an ecological niche with biotic and abiotic components. Biotic components comprised humans, plants and pet animal in houses, while abiotic factors are temperature, humidity and house structure. Collectively, all the components provide blood meals, water for aquatic stage in house with aquatic plant or unclean rubbish and resting place for adults at various elevations in high-rise apartment. Chadee (2004) reported that the adaptive quality of *Ae. aegypti* to house design had improved from ground floor to higher elevation apartment buildings. Tinker (1974) suggested that the movement of *Ae. aegypti* above the ground level may result from the insecticide pressure on breeding sites at ground level.

Aedes albopictus was dominant in UM, similarly reported by Wan-Norafikah *et al.* (2009) and Chen *et al.* (2009). The typical habitats for *Ae. albopictus* to breed are natural containers, tree holes and bamboo stumps near human dwellings (Foo *et al.*, 1985; Hawley, 1988). Rudnick *et al.* (1986) reported that *Ae. albopictus* has a preference for forest-fringe habitats and well-vegetated habitats with trees. Similarly, in this study the 12th Residential College was surrounded by trees and other vegetation. The absence of *Ae. aegypti* in UM may be due to the lack of preferred breeding condition. The environment of 12th Residential College was generally clean with minimal potable containers since piped water supply is also available.

In Table 3, the results showed that *Ae. aegypti* can be found in highest floor in KB, KK and HT and *Ae. albopictus* in UM. The highest building in this study is HT which is 16 floors in height (45.1–48.0 m). The results suggested that *Aedes* mosquitoes could have been transported by human either by way of elevators or stairs. These results were similar to a study by Liew & Curtis (2004) who reported that ovitraps with rubidium (Rb^-) marked eggs of *Ae. aegypti* and *Ae. albopictus* recovered from third level until twenty first level (60.0 m) while Chadee (2004) reported *Ae. aegypti* can be found in high-rise apartment up to 60.0 m.

Among 4 high-rise apartments, the waste management and sanitation status of HT is poor compared to other apartments. Rubbish can be seen everywhere and the dumpsite was improper where the rubbish were placed outside instead inside the big container. Moreover, the drainage system of the apartment was poor where stagnant water accumulated in corridors and in the drain after raining which can provide breeding site for *Aedes* mosquitoes. This was supported by Chen *et al.* (2005), who reported that drainage system with stagnant water served as a good artificial breeding site for *Aedes* mosquitoes. According to Knudsen & Slooff (1992), garbage collection services and surface-water drainage system combined to create favourable habitat for vectors and may lead to vector-borne disease outbreak. This support the finding that HT obtained the highest OI compared to other apartment, while UM is generally clean with minimal natural container which leads to low OI. Ho *et al.* (2004) in Hong Kong reported that cleanliness is among the eight key environmental qualities that contributed to good health and hygienic apartment which subsequently guarantee occupants' health. Ho *et al.* (2004) also stated that unhygienic environment not only created nuisance to occupants, but was also conducive to pest problem and growth of micro-organism, which led to infectious diseases outbreak.

In conclusion, this study confirmed that ovitrap surveillance is still a reliable and sensitive tool for detecting the presence of dengue vectors. This study showed that the *Aedes* mosquitoes had invaded and adapted to the high-rise ecosystem and this invasion can enhance the transmission of dengue especially when little or no vector control effort is conducted at the higher elevations. Integrated vector management (IVM) comprising surveillance, source reduction, education and public awareness, biological control, chemical control as well as personal protection should be carried out to suppress the *Aedes* populations, especially when the ovitrap index is 10% or higher (Lee, 1992b). In Trinidad, West Indies, Chadee (1988) reported that for security reasons, many apartments are closed for most parts of the day and vector control is difficult to execute. This phenomenon also can be seen in Malaysia. Thus, the IVM should be developed to educate households on the potential breeding sites around the high-rise apartment as well as suitable vector control measures in order to prevent future threats of dengue transmission. To prevent breeding of *Aedes*, operations and maintenance are crucial. Operations refers to standards of cleaning, pest control and refuse handling conditions, whereas maintenance refers to the inspection and maintenance of various building service such as water supply and drainage system.

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