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# Updated abundance and distribution of *Aedes albopictus* (Skuse) (Diptera: Culicidae) in Penang Island, Malaysia

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**Abstract.** Reduction of dengue cases and forecast its risk, and identification of vectors breeding habitats and their abundance is the prime target in any dengue control programme. In this aspect, larval surveys were conducted in four localities in Penang Island between September 2015 to September 2016. The abundance of *Aedes* mosquitoes and their breeding habitat both indoor and outdoor were recorded. *Aedes* indices i.e. Container index (CI), House index (HI) and Breteau Index (BI) were calculated for dengue risk, besides the attraction and repulsion (RF) of 5 container type evaluation. Among a total of 2,415 potential habitats examined, 638 were found positive for immature stages of *Aedes*. A total of 23,319 immatures were collected from the selected areas. *Aedes albopictus* (93.7%) was the dominant species followed by *Aedes aegypti* (5.8%) and others (0.5%). Among the 5 container types, plastic type containers were the most productive (45.5%) whereas the natural containers (6.1%) were the least ($P < 0.05$). High values of *Aedes* indices showed that all selected localities are at risk of dengue due to high prevalence of *Ae. albopictus*. Rubber and natural type of containers were the most attractive breeding habitats for vectors of dengue. The results of this study provides an insight to the current distribution of dengue vectors, which may be crucial to the health authorities in vector management programmes in the future.

## INTRODUCTION

Some genera of the Culicidae family, namely *Anopheles*, *Aedes* and *Culex* are competent vectors of the several diseases and have greatly contributed to the spread of these deadly pathogens around the globe. These three genera are the primary interest of entomologists due to their special role in the outbreaks of malaria, dengue, Zika and chikungunya (Weaver & Reisen, 2010). In 2014, the World Health Organization (WHO) estimated that malaria and dengue contribute up to 17.0 % of the global burden of infectious diseases (WHO, 2014). Recent studies have shown a decline in malaria, and an upsurge in dengue and zika incidences (Benelli & Mehlhorn, 2016). Approximately half of the world population is in danger of dengue which is evident from the increased number of dengue cases in recent years (Bhatt *et al.*, 2013). The upsurge in the number of dengue cases is due to the global expansion of these two highly competent vector species, namely *Aedes aegypti* and *Aedes albopictus* (Kraemer *et al.*, 2015). In Malaysia, dengue was first reported in Penang in 1902 (Skae, 1902) and remained endemic in the country with 223 reported mortalities in 2016 (WHO, 2017).

*Aedes aegypti* is highly anthropohilic and prefers to reside inside or near human dwellings in the urban areas (Juliano & Lounibos, 2005). Whereas *Ae. albopictus* is an aggressive, exophagic and exophilic mosquito, which can be found in rural and suburban areas and usually breeds in outdoor environment (Paupy *et al.*, 2009). However, the overlapping distribution of both container dwelling vectors has been documented from

Malaysia (Chen *et al*., 2006; Rozilawati *et al*., 2007; Roslan *et al*., 2013).

In Malaysia, *Ae. albopictus* is considered the most important vector species due to its epidemiological capability as a carrier of several arboviruses. This species, especially in Penang Island, is the most relevant vector species which has drawn the attention of the vector control authorities. Because of its adaptation to indoor breeding behavior (Dieng *et al*., 2010), along with its abundance in the urban, suburban (Rozilawati *et al*., 2007), and rural areas (Saifur *et al*., 2012a). *Ae. albopictus* has also been documented as one of the dominant species in dengue outbreak areas (Mohiddin *et al*., 2015; Rozilawati *et al*., 2015) as well as in communal spots (Maimusa *et al*., 2017). Being a superior competitor at the larval stage in nature, and capable of displacing other *Aedes* species, it has been found in major proportion as compared to other *Ae.* species (Braks *et al*., 2004; Kesavaraju *et al*., 2014). Similar observations have been reported during the larval surveillance study in the urban areas of Penang Island, where *Ae. albopictus* was found replacing *Ae. aegypti* (Maimusa *et al*., 2017).

Regardless of several novel advances in dengue virus and vector control efforts and their implementations, Malaysia has attained a limited success in dengue control (Lee *et al*., 2015). Although, several vector control strategies have been integrated to control these mosquitoes, breeding source destruction is still the key practice to maintain vector population below a threshold level (Bowman *et al*., 2016). Prior to the source destruction activities, identification of the potential breeding habitats of dengue vectors is essential for its effectiveness (Saifur *et al*., 2013), which eventually reduces the use of insecticides. Adequate information on vector abundance and spatial distribution of a species is considered as a critical factor to predict the risk of diseases caused by mosquito vectors (Juliano & Lounibos, 2005; Kweka *et al*., 2015). It is urged to periodically monitor vector density in a disease control or vector surveillance program (Britch *et al*., 2008). In addition, the identification and productivity of the most relevant containers is required (Valenca *et al*., 2013).

Human activities like urbanization, deforestation and the use of insecticides have altered the behavior of dengue vectors. These changes in breeding habitats have already been reported in both species in Penang Island. *Ae. aegypti* is found breeding outdoor (Saifur *et al*., 2012b), and *Ae. albopictus* has successfully adapted to indoor breeding environment (Dieng *et al*., 2010). Familiarities with such changes in the breeding ecology of these vectors are crucial for the management of control interventions. A few vector surveillance studies, using ovitrap and identification of breeding habitats have been carried out in Penang Island between the period of 2009 to 2011 (Saifur *et al*., 2012a; Saifur *et al*., 2013; Mohiddin *et al*., 2015; Rozilawati *et al*., 2015). However, to the best of our knowledge no further study has been conducted on the breeding habitats of *Aedes* around human dwellings since then.

This study, therefore seeks to fulfil the gaps and to update the current status of vector abundance and preferred breeding habitats in Penang Island using larval survey method.

## MATERIALS AND METHODS

The present study was undertaken in four residential areas of tropical Penang Island, Malaysia over a period of 13-months. The Island is located between latitudes 5° 8_N and 5° 35_N and longitudes 100° 8_E and 100° 32_E. The climate is tropical, with a temperature range of 23.5 to 31.4°C, relative humidity (RH) of 60.9 to 96.8%, and average annual rainfall range from 2670 to 3250 mm (Ali *et al*., 2011). However, during the study period the monthly temperature was between 26.2 to 29.0°C, with a RH of 69.8 to 82.8% and average rainfall of 30.2 to 507.4 mm was reported. The metrological data was obtained from the Penang meteorological station, Bayan Lepas Pulau Pinang, Malaysia. This study was undertaken in four residential areas of Penang namely, Gelugor, Sungai Nibong (Sg. Nibong), Permatang Damar Laut

(P.D. Laut), and Balik Pulau. Container surveys were initiated in September 2015 and completed in September 2016.

On fort-nightly basis, selected localities were surveyed entomologically, starting from 0900 to 1500 h, with 2 teams of 3 persons constituted with at least one medical entomologist. Before visiting a house, permission was acquired from the house member to survey the premises and the purpose of study was clarified using Bahasa Melayu (Malay) translated letter of introduction as described previously (Rahim *et al*., 2016). A very keen and thorough observations of the houses were attempted. All the accessible houses were inspected for the indoor and outdoor breeding habitats of *Aedes*, spending 10-15 minutes per house. Here we referred indoor containers that were under the house structure (porches), however, those outside the structure but within the territory of the houses were classified as outdoor containers as mentioned elsewhere (Rozilawati *et al*., 2015). The containers were considered as positive when found infested even with a single immature. Besides this, natural breeding sites other than the artificial containers like tree holes and some plants axils were also inspected. All containers, containing water, were examined for the presence of immature and the size and holding capacity of containers were recorded. The aquatic content containing immature were poured into plastic bags, and labelled according to the date, site and type of the containers. Depending on the size and situation of breeding source, larvae and pupae were collected using turkey baster, small fishing net or with small plastic pipette from small breeding places. Torch light was used to observe the presence of larvae in the dark conditions. The content of turbid containers was sieved and shifted into plastic containers, containing clean water to observe the presence of immatures. All preimaginal stages were transported to the laboratory on the same day. Maximum individuals were identified at larval stage, whereas the remaining were cultured to adults and identified using the keys provided by (Pratt, 1969; Rattanarithikul *et al*., 2010).

**Data analysis**

Containers were categorized into 3 sizes such as; containers with water holding capacity of > 10 liter were considered as large, > 1 liter and < 10 were medium and containers with holding capacity of <1 Liter were classified as small. Meanwhile, positive containers were identified under 5 different categories by type namely: plastic, metal, cement, rubber and natural. Entomological indices, the Container index (CI) (percentage of positive containers with immatures), the House index (HI) (percentage of infested houses) and the Breteau index (BI) (number of infested containers per 100 houses surveyed) for each of the locality were calculated to determine the *Aedes* larval densities. The values of CI > 3, HI > 4 and BI > 5 were taken as the indicators of dengue epidemic risk (Weeraratne *et al*., 2013). Risk factor (RF) for the 5 container types (X) was calculated using the following formula.

$$RF_X = \frac{\text{No. of infested containers X / no. of infested containers}}{\text{No. of potential breeding habitats X / no. of potential breeding habitats}}$$

Equivalent to:

$$RF_X = \frac{CI_X}{CI}$$

The values of RF greater than 1 indicates the attractiveness of the containers (at risk), whereas a value less than 1 means the containers are not attractive (no risk) (Favier *et al*., 2006; Weeraratne *et al*., 2013). After the data were tested for normality, differences between the containers size and number of immature were analyzed using One-way ANOVA, while distribution of *Aedes* immature among the localities was compared using the non-parametric Kruskal-Wallis test. All the data were subjected to SPSS version 22 for the analysis and the significant differences were expressed at P value < 0.05.

## RESULTS

A total of 800 houses were visited during the survey period. Among the visited houses 186 (23.3%) were found positive for *Aedes*, of which a higher percentage of positive houses was reported from P.D. Laut (28.5%), followed by Balik Pulau (27.0%), Sg. Nibong (21.5%) and the Gelugor (16.0%). Among these *Aedes* infected houses, 49 (26.3%) houses were found with indoor breeding whereas 137 (73.7%) houses with outdoor breeding (Table 1). Among the indoor positive houses, 20.4% were positive with *Ae. aegypti* while 79.6% of houses were positive with *Ae. albopictus*. The percentage of indoor and outdoor positive houses for both species are presented by locality in Table 1.

In all the locations, a total of 2,415 potential breeding habitats were found and out of these habitats 638 were found positive with *Aedes* immatures. Among the positive habitats, a total of 23,319 immatures were found. *Aedes albopictus* (93.7%) was the dominant species in all the locations followed by *Ae. aegypti* (5.8%). In addition to both *Aedes* species, *Culex* and *Toxorhynchites* (0.5%) immatures were also observed. Statistical analysis, Kruskal Walis Test, showed that the distribution of immature was similar among the localities ($\chi^2 = 1.467$, df = 3, $P > 0.05$) (Table 2). Besides mosquito larvae, an uncounted number of red midge larvae (Chironomids) was observed in the containers.

Table 3 shows that in all the surveyed localities, plastic type containers contained the highest number of immatures with a positive percentage of 45.2%, followed by metal (22.8%), cement (17.1%), rubber (8.8%), and natural (6.1%) containers. Significant differences were seen between the containers types in terms of immature productivity ($\chi^2 = 16.614$, df = 4, $P < 0.05$). Whereas, medium size containers were the most imperative to produce huge number of immatures with a percentage positivity of 45.3% followed by large and small size containers with values of 26.6 and 27.1%, respectively. One-way ANOVA test results reveals that there is no difference between

Table 1. Total number of houses positive indoor and outdoor in selected localities with both species

| Location | Total houses visited | Indoor positive | Outdoor positive | Total (%) | Indoor positive houses *Ae. aegypti* | Indoor positive houses *Ae. albopictus* | Outdoor positive *Ae. aegypti* | Outdoor positive houses *Ae. albopictus* |
|---|---|---|---|---|---|---|---|---|
| Gelugor | 200 | 9 | 23 | 32 (16.0%) | 03 | 6 | 6 | 17 |
| Sg. Nibong | 200 | 11 | 32 | 43 (21.5%) | 06 | 5 | 4 | 28 |
| P.D. Laut | 200 | 14 | 43 | 57 (28.5%) | 01 | 13 | 06 | 37 |
| Balik Pulau | 200 | 15 | 39 | 54 (27.0%) | 0 | 15 | 3 | 36 |
| Total | 800 | 49 | 137 | 186 (32.2%) | 10 | 39 | 19 | 118 |

Total 2. Total number of positive containers and immature collected from the four locations during the study period

| Locations | Total positive containers | *Ae. albopictus* | *Ae. aegypti* | Others (*Culex* + *Toxorhynchites*) | Total |
|---|---|---|---|---|---|
| Gelugor | 126 | 3,217 | 669 | 49 | 3,935 |
| Sg. Nibong | 133 | 5,186 | 393 | 33 | 5,612 |
| P.D.Laut | 197 | 7,042 | 187 | 20 | 7,249 |
| Balik Pulau | 182 | 6,401 | 109 | 13 | 6,523 |
| Total | 638 | 21,846 (93.7%) | 1,358 (5.8%) | 115 (0.5%) | 23,319 |

Kruskal Wallis test $P > 0.05$.

Table 3. Total number of immatures and productivity[1] of containers (%) by five types in four localities

| Containers type | Localities | | | | Total (%) |
|---|---|---|---|---|---|
| | Gelugor Total (%) | Sg. Nibong Total (%) | P.D. Laut Total (%) | Balik Pulau Total (%) | |
| Plastic | 1,791 (45.5%) | 2,862 (51.0) | 3,434 (47.4) | 2,449 (37.5) | 10,536 (45.2) |
| Metal | 980 (24.9) | 1,122 (20.0) | 1,763 (24.3) | 1,459 (22.4) | 5,324 (22.8) |
| Cement | 568 (14.4) | 730 (13.0) | 1,162 (16.0) | 1,527 (23.4) | 3,987 (17.1) |
| Rubber | 305 (7.8) | 561 (10.0) | 548 (7.6) | 630 (9.7) | 2,044 (8.8) |
| Natural | 291 (7.4) | 337 (6.0) | 342 (4.7) | 458 (7.0) | 1,428 (6.1) |

[1] Productivity = number of immatures collected × 100/ total number of immatures.
Kruskal Wallis test P < 0.05.

Table 4. Total number and percentage of immatures collected from four localities by size

| Container size | Localities | | | | Total (%)* |
|---|---|---|---|---|---|
| | Gelugor Total (%) | Sg. Nibong Total (%) | P.D. Laut Total (%) | Balik Pulau Total (%) | |
| Large | 773 (19.6) | 1,627 (29.0) | 1,958 (27.0) | 2,087 (32.0) | 6,445 (27.6) |
| Medium | 2,061 (52.4) | 2,246 (40.0) | 3,769 (52.0) | 2,480 (38.0) | 10,556 (45.3) |
| Small | 1,011 (28.0) | 1,739 (31.0) | 1,522 (21.0) | 1,956 (30.0) | 6,318 (27.1) |

* One way ANOVA values showed that no significant difference in the number of immatures P = 0.056.

Table 5. Total and individual *Aedes* indices Container index (CI), House index (HI) and Breteau (BI) for *Ae. albopictus* and *Ae. aegypti* calculated for the four study sites

| | [1]Gelugor | | | Sg. Nibong | | | P.D. Laut | | | Balik Pulau | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | [2]*AL* | [3]*AG* | Total | [2]*AL* | [3]*AG* | Total | [2]*AL* | [3]*AG* | Total | [2]*AL* | [3]*AG* | Total |
| CI | 18.9 | 2.8 | 20.9 | 24.5 | 1.4 | 25.9 | 26.6 | 2.3 | 28.9 | 28.8 | 0.6 | 29.5 |
| HI | 14 | 4.5 | 18.5 | 19.5 | 2 | 21.5 | 25 | 3.5 | 28.5 | 26 | 1 | 27 |
| BI | 57 | 8.5 | 63 | 63 | 3.5 | 66.5 | 90.5 | 8 | 98.5 | 89 | 2 | 91 |

[1]Mixed breeding only in 5 containers.
[2]*AL*, *Ae. albopictus;* [3]*AG*, *Ae. aegypti.*

the number of immatures for all size container (F = 4.037, df = 2, $P$ = 0.056) (Table 4).

Table 5 shows the values of *Aedes* indices for both species in the four selected locations. During the survey period, mixed breeding of both *Aedes* species was observed only in Gelugor in 5 containers. Values of *Aedes* indices higher than the defined values (CI > 3, HI > 4 and BI > 5) showed that all the localities are at risk of dengue. The HI individual indices value of 4.5 for *Ae. aegypti* shows that Gelugor is at moderate risk, but on the hand, Gelugor and P.D. Laut are at risk due to high BI values of 8.5 and 8, respectively due to this species. Whereas, all the localities are at high risk of dengue due to the massive existence of *Ae. albopictus*. *Aedes* indices values showed that Balik Pulau has a high epidemic risk, whereas Gelugor has the least. Mosquito's immatures were found almost all year round. The highest CI, HI and BI were recorded in September 2016, whereas the lowest values were recorded in March 2016. Overall monthly *Aedes* indices are presented in Figure 1.

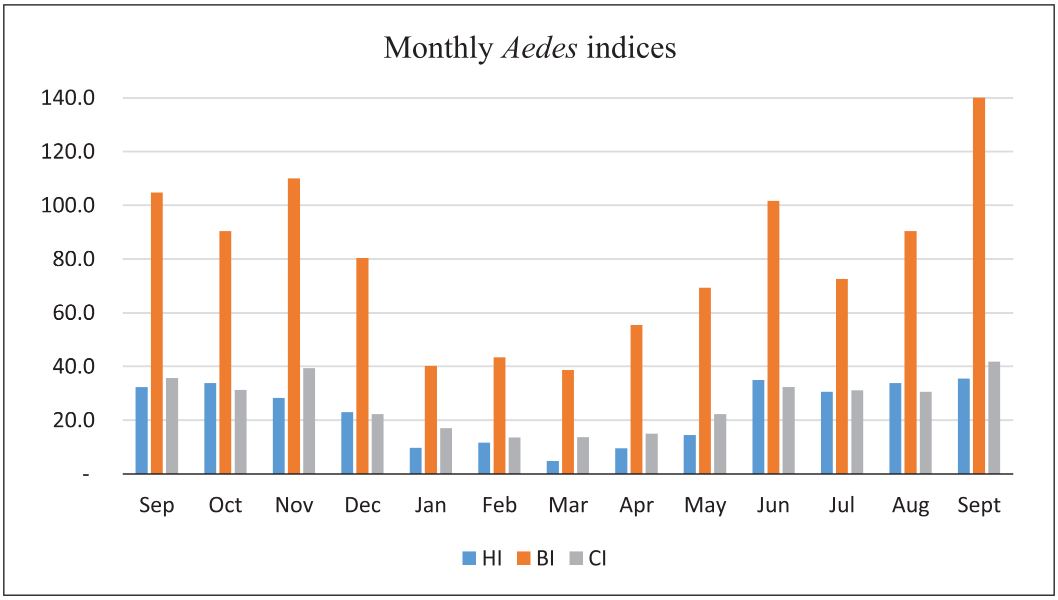


Figure 1. Monthly *Aedes* indices house index (HI), Breteau index (BI), and container index (CI) in selected localities during the study period.

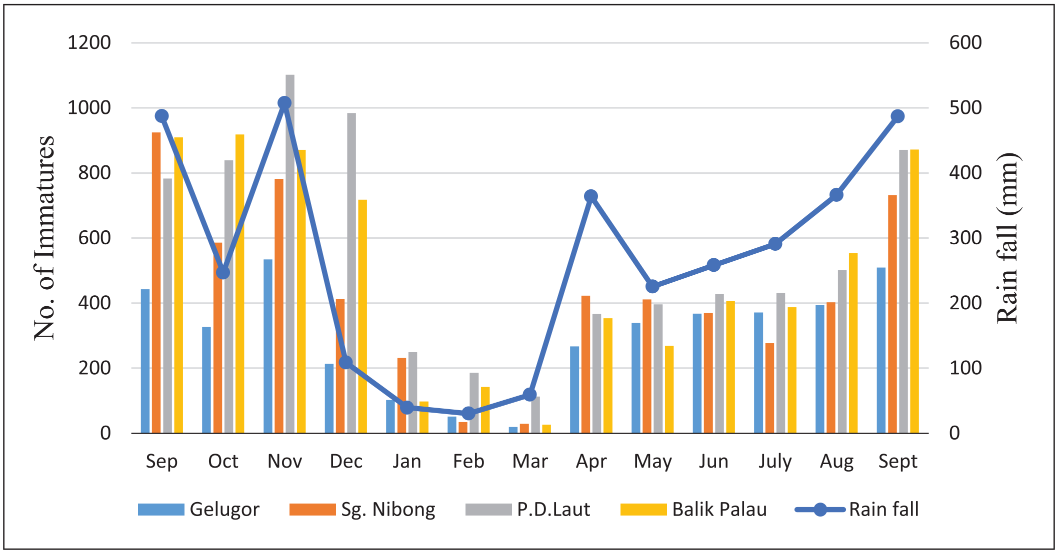


Figure 2. Relationship between rainfall and number of immatures in four selected localities.

A significant positive correlation was found between the rainfall and the number of immatures at all locations. At Gelugor, the relationship for rainfall was r = 0.925, *P* < 0.001, Sg. Nibong (r = 0.860, P = < 0.001), Balik Pulau (r = 0.732, P = 0.004), whereas a weak relationship was observed in P.D. Laut between rainfall and number of immatures (r = 0.617, P = 0.025) (Figure 2). The correlation of temperature with number of immatures at Gelugor was insignificant (r = 0.029, P > 0.05), Sg. Nibong (r = 0.003, P > 0.05), P.D. Laut (r = 0.004, P > 0.05) and Balik Pulau (r = 0.003, P > 0.05). Similarly, no significant correlation was found between the number of immatures and relative humidity in all the locations i.e. Gelugor was ($r = 0.002$, $P > 0.05$), Sg. Nibong ($r = 0.106$, $P > 0.05$), P.D. Laut ($r = 0.142$, $P > 0.05$), Balik Pulau ($r = 0.156$, $P > 0.05$).

Among the positive breeding container types, rubber type containers, tyres and shoes were the most attractive breeding habitats in all the localities. Plastic and cement containers were the second most attractive breeding habitats. Metal and cement type containers were the repulsive habitats with the marginal risk factor value of 0.9 in Gelugor. In Sg. Nibong the high RF value (2) was observed for rubber type breeding habitats, followed by natural, cement, metal and the least was plastic with the values of 2.0, 1.6, 1.3, 1.0 and 0.9, respectively. While in P.D. Laut, except natural containers (RF = 0.8), the rest of container types were attractive with the range of RF values 1.0 to 1.5. Metal type containers were the repulsive (RF = 0.8) breeding habitats in Balik Pulau while the attractive values of 1.9, 1.7, 1.3 and 1.2 for rubber, cement, natural and plastic type containers respectively were observed.

## DISCUSSION

Malaysia is a endemic country for dengue due to its favorable climatic conditions for the successful breeding of mosquitoes. *Aedes* indices obtained from immature inspections in dengue outbreak areas have been the motive for the vector surveillance program in Malaysia (Azil *et al.*, 2011). Results of the present study showed that *Ae. albopictus* is the dominant species in the selected localities. During 2009, a vector surveillance study conducted in Penang Island revealed that *Ae. aegypti* was the dominant species in urban areas of Penang, including Gelugor and *Ae. albopictus* was the dominant species in highly vegetative (Rural) areas (Saifur *et al.*, 2012a). However, the results presented here reveals that *Ae. albopictus* (82.2%) has currently become the dominant species in the urban areas of Gelugor as compared to *Ae. aegypti* (17.2 %). These findings supported the evidences of recent field studies on public places which showed that it was dominated by *Ae. albopictus* in Penang Island (Maimusa *et al.*, 2017). Chen *et al.* (2009) reported the complete absence of *Ae. aegypti* in a suburban areas of Kuala Lumpur. In a separate study conducted in the highly developed area of Shah Alam (Malaysia), *Ae. albopictus* (90.7%) was found to be the dominant species (Faiz *et al.*, 2017).

The findings of dengue vector surveillance studies in Malaysia are consistent with studies carried out in different countries, showing a major decline in the abundance of *Ae. aegypti* and the invasion of *Ae. albopictus* in the urban areas (Hobbs *et al.*, 1991; Kaplan *et al.*, 2010; Beilhe *et al.*, 2012; Weeraratne *et al.*, 2013). As reported, *Aedes albopictus* is an aggressive mosquito species which competes with other species in several ways and it is has the competitive advantages over *Ae. aegypti* in field conditions (Juliano *et al.*, 2004; Juliano, 2010). Inter-specific competition between *Aedes* species have reported in several studies which showed the the displacement of *Ae. aegypti* (Lounibos, 2002) and *Ae. sierrensis* (Kesavaraju *et al.*, 2014) by *Ae. albopictus* in their native areas. Although, the current results do not provide a competition between these two species, but the low density of *Ae. aegypti* provides evidence that *Ae. albopictus* has invaded the urban areas of Penang.

The present results indicate that *Ae. aegypti* is not completely displaced from the containers and possibly may have adopted different breeding habitats in Penang Island in a similar way as reported in Brazil (Paploski *et al.*, 2016) and Singapore (Seidahmed & Eltahir, 2016). In these two countries, the storm drains were found containing *Ae. aegypti* population. Moreover, other environmental factors such as, high temperature and precipitation could be the reasons for the successful growth of *Ae. albopictus* (Neto & Navarro-Silva, 2004) as compared to the development of *Ae. aegypti* (Grech *et al.*, 2015). The temeperature can reach up to 35°C in Penang Island (Saifur *et al.*, 2013), and this temperature range is unfavorable for the pupation of *Ae. aegypti* (Kumar *et al.*, 2016).

The ovitrap and larval surveys conducted on Penang Island during 2011 by Rozilawati *et al.* (2015) reported high abundance of *Ae. albopictus* in ovitraps as compared to *Ae. aegypti* and vice versa for containers in the selected localities of Gelugor and P.D. Laut. The present larval study reveals that *Ae. albopictus* was dominant in containers in both studied areas. Meanwhile, a low percentages of *Ae. aegypti* larvae encountered during the survey confirmed its presences in Balik Pulau. Previous findings by Saifur *et al.* (2012a) reported this area was free of *Ae. aegypti* between 2009–2010 and predicted that the frequent traffic from urban areas may cause this species to spread to this area.

Several characteristics of plastic such as, durability, easy to recycle, light weight, and low cost, has encouraged the industries to design plastic made products for a wide range of usage. Together with several socioeconomic factors, plastic type containers have been found the most productive breeding habitats in several parts of the world (Chareonviriyaphap *et al.*, 2003; Banerjee *et al.*, 2015; Verna, 2015; Dhar-Chowdhury *et al.*, 2016), including Malaysia (Saifur *et al.*, 2013; Rozilawati *et al.*, 2015; Faiz *et al.*, 2017; Maimusa *et al.*, 2017). During the present study period, a wide range of plastic type containers were found dispersed and suitable for *Ae. albopictus* breeding.

Routine inspection of *Aedes* infested containers is a standard method in vector control program (Chadee, 2004). The values of *Aedes* indices (CI > 3, BI > 4 and HI > 5) observed in the current study indicates that, the population density of *Aedes* and the potential breeding habitats were high enough to be a threat for dengue outbreaks. Results of the present larval survey showed that all the selected localities on Penang Island are at dengue risk due to the high prevalence of *Ae. albopictus*. Previously, this vector species was also found dominant in an ovitrap based study conducted in dengue outbreak areas of Penang Island (Mohiddin *et al.*, 2015). *Aedes albopictus* is a competent vector for all dengue serotypes, and naturally contain dengue virus during the dry season (Thenmozhi *et al.*, 2007). In Malaysia, transovarial transmission of serotype 2 has been detected from the wild caught larvae of *Ae. albopictus* (Rohani *et al.*, 2014).

Regarding the indoor and outdoor breeding preference of both vectors, the observations were similar to the previously conducted studies on Penang Island (Saifur *et al.*, 2012a; Rozilawati *et al.*, 2015). Both indoor and outdoor containers were found feasible for *Ae. albopictus* breeding. However, high number of positive containers was seen outside the houses, which serves as more potential breeding habitats during the rainy season as compared to indoor containers. It is likely due to the high nutrient contents and the lesser frequency of changing water in outdoor containers as compared to indoor containers. In an early investigation, similar probabilities were also observed for *Ae. aegypti* breeding in outdoor containers in Iquitos, Peru (Schneider *et al.*, 2004). In general, female *Ae. albopictus* preferably lays eggs in more than 2 containers during a single gonotrophic cycle (Davis *et al.*, 2015; Davis *et al.*, 2016). Moreover, skip oviposition behavior may also assist *Ae. albopictus* in harboring more outdoor containers.

Interestingly, high number of *Ae. aegypti* immature was collected after the moderate rain fall as compared to low rain fall season lasted in the month of April 2016 starting from January (Same year). A possible reason for such observation can be the egg desiccation tolerance of both *Aedes* species. As compared to *Ae. albopictus*, eggs of *Ae. aegypti* are more resistant to the drought environmental conditions (Juliano *et al.*, 2002), which favors *Ae. aegypti* by reversing competitive advantages (Juliano & Lounibos, 2005). Furthermore during the dry season in Bangladesh, Chowdhury *et al.* (2014) observed *Ae. albopictus* females utilizing treeholes debris for the survival of their further progenies.

Undouble, the direct impact of climatic conditions such as rain fall and temperature pose great impact on the life aspects of mosquitoes. As stated before, several studies have found that dengue vector and disease cases are positively associated with environmental conditions. Besides the positive impact of rain fall, simulated field trials have shown a negative impact of heavy rain fall on immatures (Dieng *et al.*, 2012). A significant impact of with rain fall, while an insignificant association between temperature relative humidity and the number of immatures was noted in this study. An increase of 0.5–1.5°C in the temperature of Malaysia have been observed between years 1998–2007, whereas 27°C is considered as an average temperature reported by Hii *et al.* (2016). In an earlier research, Saifur *et al.* (2013) reported an up surge in the temperature up to 35°C in Penang during their survey in 2009. Besides the effect of temperature range on vector biology, it also has an impact on the dengue virus replication and incubation period.

Along with the other characteristics, attraction in *Aedes* towards black colour is their innate behaviour and a huge number of studies have reported that tyres are the most preferred breeding habitat of these vector species. Laboratory based studies on the oviposition behaviour of *Ae. albopictus* have also shown the preferred attraction towards black colour jars (Yap *et al.*, 1995). In this study, high RF was observed for rubber and natural containers compared to other artificial habitats. In another study, the CI values for natural containers (44.4%) and (37.9%) for tires have been reported from Shah Alam (Faiz *et al.*, 2017). The attraction towards colour and high nutrients in natural containers makes them attractive for the oviposition. Plastic type containers accounted for 45.0% of all immature collected and was highly abundant but do not posed a high risk factor. In Sri Lanka, similar patterns of RF were found for both dengue vectors for tyres, however the leaf axils were repulsive breeding habitats (RF=0.64) for *Ae. albopictus* (Weeraratne *et al.*, 2013). In a separate study, Morrison *et al.* (2004) stated that, targeting plastic containers in a source destruction programme is inappropriate due to its high abundance but low infestation rate of 3.6% as compared to the other containers.

Current survey shows that, *Ae. albopictus* is the main competing vector in Penang Island. However, further studies are required for deeper understandings of how larval competition and type of containers can affect the life history traits and abundance of this vector species. Beside this, the influence of environmental variables, quality and quantity of resources in containers on adults should be studied. The interspecific mating studies between *Ae. albopictus* and *Ae. aegypti* should be carried out in field to investigate the distribution of species. Furthermore, vectorial capacity of these vectors should be studied in the areas where they coexist. Several vector surveillance studies have been carried out on Penang Island, but still there is no account of circulating virus type in these species. Besides targeting key breeding containers, it is also essential to survey and target storm drains and drainage lines which facilitate the breeding of *Ae. aegypti* in some areas.

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