TEMPORAL CHANGES OF *AEDES* AND *ARMIGERES* POPULATIONS IN SUBURBAN AND FORESTED AREAS IN MALAYSIA

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Abstract. Surveillance of mosquitoes and their distribution in association with rainfall, relative humidity, and temperature were conducted in selected suburban and forested areas, namely, Sungai Penchala (Kuala Lumpur) and Taman Alam (Selangor) for 12 months. *Armigeres kesseli* was the most abundant species in Sungai Penchala while *Aedes butleri* was the most dominant species in Taman Alam. A positive correlation between mosquito distribution and rainfall was observed in selected mosquito species in Sungai Penchala (*Armigeres kesseli*, r=0.75; *Armigeres subalbatus*, r=0.62; and *Aedes albopictus*, r=0.65) and Taman Alam (*Armigeres* sp, r=0.59; *Ae. butleri*, r=0.85; and *Ae. albopictus*, r=0.62). However, no significant correlation was found either between selected mosquito species in both study areas and relative humidity or temperature. Results obtained suggested that vector control programs to be conducted based on temporal distribution of vectors in order to achieve beneficial outcomes with effective costing.

Keywords: *Aedes*, *Armigeres*, human landing catch, temporal changes, Malaysia

INTRODUCTION

Dengue, malaria, filariasis and several types of encephalitis are known to be transmitted by mosquitoes. *Aedes* mosquitoes are the major concern above all other mosquito species due to its ability to transmit dengue viruses (Lee, 2000). A total of 82,738 dengue cases with 157 deaths were reported in Malaysia from January 2014 until 18 October 2014, compared to 26,527 dengue cases with 59 deaths reported within the same duration in 2013 (unpublished data, Ministry of Health Malaysia, 2014).

The abundance of mosquitoes has always been associated with rainfall, temperature, and humidity as well as the presence of the host. In order to control or predict the outbreak of mosquito-borne diseases, study of the seasonal abundance of mosquitoes plays an important role

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(Promprous *et al*, 2005).

According to Dhiman *et al* (2008), temperature influences the developmental process of different stages of the mosquito life cycle, which includes blood feeding rate, gonotrophic cycle, and longevity. When the temperature is within the favorable range of activity, the rate of blood meal digestion increases, which then accelerates ovarian development, producing more eggs and leading to a higher feeding frequency on hosts, thereby increasing the probability of transmitting diseases to human.

Another major factor affecting mosquito seasonal abundance is the rainfall. Rainfall plays an important role in determining the abundance of the outdoor-breeding mosquito population (Rozilawati *et al*, 2007). Wet seasons are associated with higher mosquito populations and increased reports on mosquito-borne diseases (Okogun, 2003). Mosquitoes usually breed after the rain and not during the rain. Rain causes the occurrence of stagnant water held by natural or artificial containers, which are common breeding places for urban mosquitoes such as *Aedes* and *Culex*. Presence of mosquito breeding sites allows oviposition of more gravid female mosquitoes which will indirectly increase the mosquito populations. As for the *Armigeres* subgroup *Leicesteria*, their interaction with rainfall is indirect. Studies by Macdonald (1960) found that during wet season, a crop of young bamboos began to appear and the population of *Leicesteria* automatically became more common. Even though the rainfall is heavy during dry season, the population of *Leicesteria* was not increased unless young bamboos increased in numbers (Macdonald, 1960). On the other hand, heavy rainfall exerts a negative impact on the mosquito population as it is plausible that excessive rainfall may flush eggs and larvae from the immature stage habitat (DeGaetano, 2005). In Malaysia, Foo *et al* (1985) suggested that negative impact of rainfall on *Aedes* house index was due to the flushing effect of heavy downpour. In some circumstances, the rain will wash all the breeding places and the mosquito population will decrease.

In addition, high relative humidity can induce high hatching rates. Craig *et al* (1999) found that relative humidity was generally high in order to maintain the basic survival rate of mosquitoes. For example. with 100% relative humidity, *Aedes aegypti* eggs can hatch on filter paper. However, in the tropics where temperature and relative humidity remain relatively constant throughout the year, the impact of both factors on egg development is minimal (Manorenjitha, 2005).

Up to our knowledge, unlike *Aedes* mosquitoes, the seasonal abundance and distribution of *Armigeres* in Malaysia had never been studied. Thus, this study was conducted to investigate the seasonal abundance and distribution of both *Aedes* and *Armigeres* in suburban and forested areas in Peninsular Malaysia.

MATERIALS AND METHODS

Study sites

The ecological descriptions of the study sites are provided in Table 1.

Mosquito collections

Mosquito collections were conducted in Sungai Penchala (Kuala Lumpur) and Taman Alam (Selangor) using the human landing catch (HLC) technique (Lee, 1994). HLC were conducted during active biting hours of *Aedes* and *Armigeres*, *ie*, from 08:00 pm until early morning. HLC were performed for three consecu-

Table 1
Ecological description of study sites.

Area	Study site	Ecological description
Suburban	Sungai Penchala, Kuala Lumpur (3°10′0″N, 101°38′ 0″E)	Surrounded by dense vegetation area and a durian orchard. Bungalow houses scattered within the site. An unplanned housing area.
Forested	Taman Alam, Kuala Selangor, Selangor (3°20′24.69″N, 101°14′33.87″E)	It covers approximately 234 acres of mangroves and mudflats and 497 acres of secondary forest. A recreational park dominated by strangling figs and other coastal trees (*eg*, *Cordia dichtama*), along with mangrove fern.

tive days every month from October 2009 until September 2010. Mosquitoes landed on exposed legs and arms of collectors were individually captured using 50 x 19 mm glass vials which were subsequently plugged off with cotton wools. Three collectors that served as human baits collected mosquitoes near potential mosquito breeding sites. Consent forms were distributed and signed by all collectors prior to HLC. Captured mosquitoes were identified and segregated according to species, date, and site. Species identification were done using keys by Huang (1972, 1979), Reid (1968), Thurman (1959) and Wharton (1962).

Data analysis

Relative mean abundance was used to measure the percentage of each mosquito species distributed within the sampling area.

The relative species abundance was calculated using the following formula:

Relative abundance (%) = Number of individuals from one group of mosquitoes (n) / Total number of individuals from all groups of species (N) x 100

Monthly rainfall data were obtained from the Malaysian Meteorological Department, while relative humidity and temperatures were recorded during the sampling period.

The association between the mean number of mosquitoes and meteorological parameters (mean rainfall, temperature, relative humidity) were studied using Pearson's correlation coefficient (r) analysis derived from SPSS (Version 15; IBM, Armonk, NY). The correlation makes no assumption as to whether one variable is dependent on the other(s) and is not concerned with the relationship between variables; instead, it gives an estimate on the degree of association between the variables (Rozilawati *et al*, 2007).

RESULTS

Mosquito abundance

A total of 7,955 adult mosquitoes belonging to six genera and 15 species were collected in both study sites throughout 12 months of this study. The species obtained were *Aedes albopictus*, *Ae. cranceraedes*, *Ae. butleri*, *Ae. gardenerii*, *Ae. niveus*, *Armigeres subalbatus*, *Ar. kesseli* , *Culex tritaeniorhynchus*, *Cx. vishnui*, *Cx. gelidus*, *Cx. quinque-*

Table 2
Number of adult mosquitoes collected from Sungai Penchala, Kuala Lumpur and Taman Alam, Selangor, Malaysia.

Species	No. adult mosquitoes collected		
	Sungai Penchala, Kuala Lumpur *n* (%)	Taman Alam, Selangor *n* (%)	Total *n* (%)
Aedes albopictus	701 (32.16)	791 (13.70)	1,492 (18.76)
Aedes butleri	0 (0)	3,059 (52.97)	3,059 (38.45)
Aedes cranceraedes	0 (0)	124 (2.15)	124 (1.56)
Aedes niveus	3 (0.14)	9 (0.16)	12 (0.15)
Aedes gardenerii	0 (0)	14 (0.24)	14 (0.18)
Armigeres kesseli	858 (39.36)	329 (5.70)	1,187 (14.92)
Armigeres subalbatus	614 (28.17)	221 (3.83)	835 (10.50)
Culex vishnui	1 (0.05)	1,073 (18.58)	1,074 (13.50)
Culex quinquefasciatus	1 (0.05)	72 (1.25)	73 (0.92)
Culex gelidus	1 (0.05)	56 (0.97)	57 (0.72)
Culex tritaeniorhynchus	0 (0)	3 (0.05)	3 (0.04)
Anopheles separatus	0 (0)	3 (0.05)	3 (0.04)
Mansonia bonneae	0 (0)	21 (0.36)	21 (0.26)
Coquillettidia crucassion	1 (0.05)	0 (0)	1 (0.01)
Total	2,180 (100)	5,775 (100)	7,955 (100)

fasciatus, *Mansonia bonneae*, *Coquillettidia crucassion* and *Anopheles seperatus*. *Aedes* was the most abundant genus recorded in Sungai Penchala and Taman Alam (59.10%), followed by *Armigeres* (25.42%), *Culex* (15.18%), *Mansonia* (0.26%), *Anopheles* (0.04%), and *Coquillettidia* (0.01%) (Table 2).

Mosquito populations were more diverse in Taman Alam as the Shannon Weiner Index (H') was higher in Taman Alam (H'=1.45) compared to Sungai Penchala (H'=1.11). *Ar. kesseli* (39.36%) and *Ae. butleri* (52.97%) were the most dominant mosquitoes in Sungai Penchala and Taman Alam, respectively (Table 2).

Seasonal abundance of mosquitoes in Sungai Penchala

In Sungai Penchala, a total of 2180 adults belonging to eight species were identified. Three species of mosquitoes showed their dominancy in Sungai Penchala, which were *Ar. kesseli* (39.36%), *Ae. albopictus* (32.16%), and *Ar. subalbatus* (28.17%). Other recorded species were *Ae. niveus* (0.14%), *Cx. quinquefasciatus* (0.05%), *Cx. vishnui* (0.05%), *Cx. gelidus* (0.05%), and *Co. crucassion* (0.05%) (Table 2). The number of mosquitoes collected in different months during the study period were significantly varied [one-way analysis of variance (ANOVA), F=19.87, $p<0.05$].

A strong positive relationship was found between number of mosquitoes collected per man and rainfall for *Ar. kesseli* (r=0.75, $p\leq0.01$), *Ar. subalbatus* (r=0.62, $p\leq0.05$) and *Ae. albopictus* (r=0.65, $p\leq0.05$) in Sungai Penchala (Fig 1). No significant correlation was found between mosquito population and humidity as well as temperature ($p>0.05$).

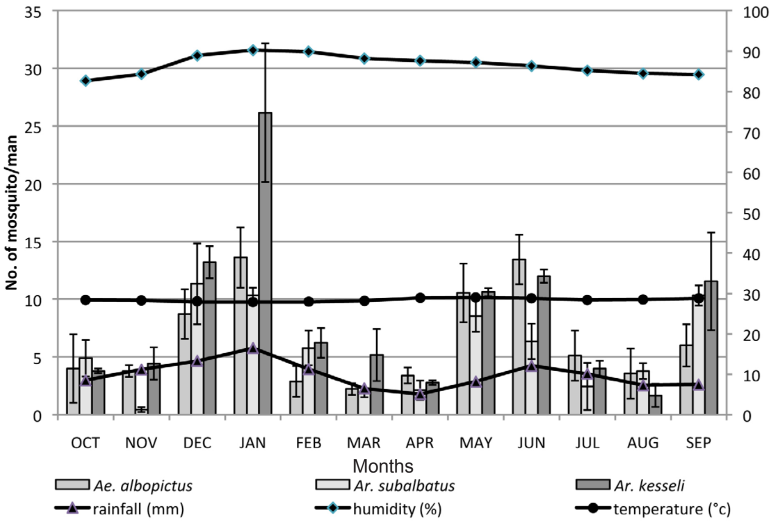

Fig 1–Correlation between mean number of mosquito/man with rainfall (*Ae. albopictus*, *r*=0.65, *p*=0.02; *Ar. subalbatus*, *r*=0.62, *p*=0.03; *Ar. kesseli*, *r*=0.75, p=0.05), relative humidity (*Ae. albopictus*, *r*=0.32, *p*=0.32; *Ar. subalbatus*, *r*=0.50, *p*=0.10; *Ar. kesseli*, r=0.53, *p*=0.08) and temperature (*Ae. albopictus*, r=0.10, *p*=0.77; *Ar. subalbatus*, *r*=-0.11, *p*=0.73; *Ar. kesseli*, *r*=-0.26, *p*=0.37) in Sungai Penchala, Kuala Lumpur.

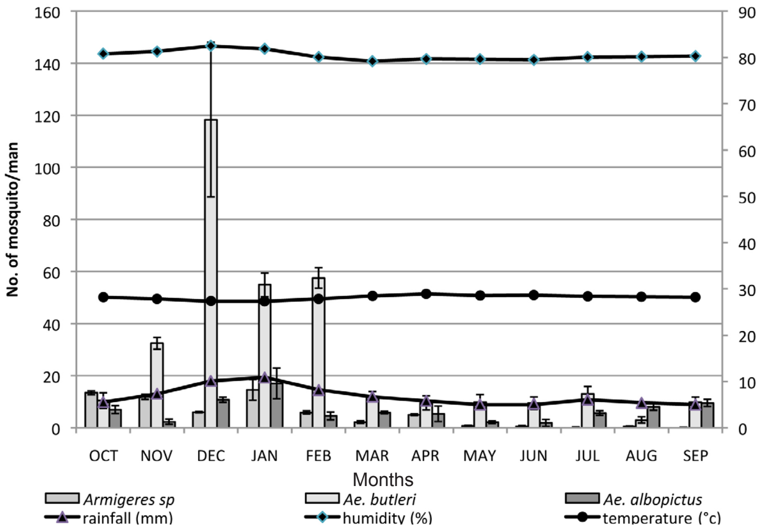

Fig 2–Correlation between number of mosquito/man with rainfall (*Armigeres* sp, *r*=0.59, *p*=0.05; *Ae. butleri*, *r*=0.86; *p*=0.00; *Ae. albopictus*, *r*=0.64, p=0.02), relative humidity (*Armigeres* sp, *r*=0.54, *p*=0.07; *Ae. butleri*, *r*=0.29; *p*=0.37; *Ae. albopictus*, r=0.18, *p*=0.56) and temperature (*Armigeres* sp, *r*=0.01, *p*=0.99; *Ae. butleri*, *r*=0.23; *p*=0.49; *Ae. albopictus*, *r*=-0.54, *p*=0.07) in Taman Alam, Selangor.

Seasonal abundance of mosquitoes in Taman Alam

A total of 5,775 mosquitoes belonging to five genera and 13 species were collected in Taman Alam throughout the study. The most dominant species in Taman Alam was *Ae. butleri* (52.97%), followed by *Cx. vishnui* (18.58%) and *Ae. albopictus* (13.70%) (Table 2). The following species, found in Sungai Penchala, were also found in Taman Alam: *Ar. kesseli* (5.70%), *Ar. subalbatus* (3.83%), *Cx. quinquefasciatus* (1.25%), *Cx. gelidus* (0.97%), *Ae. niveus* (0.16%), and *Cx. tritaeniorhynchus* (0.05%). Additional species found in Taman Alam were *Ae. cranceraedes* (2.15%), *Ae. gardenerii* (0.24%), *An. separatus* (0.05%) and *Ma. bonneae* (0.36%). The number of mosquitoes obtained from different months were significantly different (one-way ANOVA, F=8.05, $p<0.05$).

Even though 13 species were found in Taman Alam, only four dominant mosquito species, namely, *Ar. subalbatus*, *Ar. kesseli*, *Ae. albopictus* and *Ae. butleri* were selected to be further studied on the association between their population distributions and meteorological conditions. Since the number of *Ar. subalbatus* and *Ar. kesseli* were low in Sungai Penchala, both species were combined and reported as *Armigeres* species.

The adult population according to mosquito/man, of *Armigeres* was 13.23±10.44, followed by *Ae. butleri* 3.40±2.99, and *Ae. albopictus* 2.65±1.50 (Fig 2). The mosquito populations increased starting from October and peaked in December. *Ae. butleri* population was peaked in December (118.33±29.68 mosquito/man), while *Armigeres* (14.55±4.00 mosquito/man) and *Ae. albopictus* (19.34±5.90 mosquito/man) populations were peaked in January. A strong relationship was found between the number of mosquitoes per man and rainfall; for *Armigeres* (r=0.59, $p \leq 0.05$), *Ae. albopictus* (r=0.64, $p \leq 0.05$) and *Ae. butleri* (r=0.86, $p \leq 0.01$), in Taman Alam. However, the mosquito populations in Taman Alam did not show any significant correlation with temperature or humidity (both $p > 0.05$).

DISCUSSION

Mosquito abundance

Government have implemented National Strategic Plan for mosquito borne diseases especially dengue in order to reduce the number of cases by half in 5 years. Integrated vector management, dengue case management, communication and social mobilization, outbreak response, research on mosquitoes are all part of the national plan in managing and controlling dengue (Chong and Arpah, 2013). In fact, according to Low *et al* (2012), mosquito surveillance is a preliminary step used in vector monitoring and control.

The large number of mosquito species captured in Taman Alam showed that this study site which consists of heavy vegetation provided variety of breeding places for different mosquito species. Presence of shrubs and trees covered a large part of the soil surface, creating a cool environment for mosquitoes to rest and breed (WHO, 2007). Evan (1938) stated that the growth of vegetation cover and a cool shaded environment supported the development of the aquatic stage of mosquitoes and the recruitment of young adults and their offspring.

According to the keeper of Taman Alam, this secondary forest was a former mangrove forest. The construction of a coastal bund left a healthy bund of mangroves on the seaward side, while the inland mangroves outside the bund gradually dried up and were replaced by a secondary forest. Thus, the soil content of this area was a mixture of mud, sand, and clay. Many water puddles could be seen along the trails inside this secondary forest and towards the mangroves during the wet season (October–January). From our observation, these water puddles never dried out and may contribute to mosquito breeding. It is a well-known fact that clay soil has the ability to hold water very well, ensuring that this place is wet and moist and providing water and nutrients to the trees (Brady and Weil, 2002). In Kenya, a study on the soil mixture suggested that clay and sandy soil were significant factors in producing fit and vector-competent *An. gambiae* (Okech *et al*, 2007). Thus, the organic matter content and microbial activity in the soil might be some of the reasons affecting the mosquito population in Taman Alam. However, further experiments need to be conducted to confirm this hypothesis.

More *Armigeres* were found in Sungai Penchala compared to Taman Alam, which may be due to the availability of breeding sites. Popular breeding sites for *Armigeres* mosquitoes, as reported by Kabirul *et al* (2005), were bamboo. In Sungai Penchala, bamboos were widely found around the sampling site. The water held by these bamboos might attract *Armigeres* to oviposit. Alwis and Munasinghe (1971) reported that alkaline conditions with a pH of 8.2 or above appeared to be a suitable breeding site for *Ar. subalbatus.* Even though the pH inside a hollow bamboo was reported to be around 5.5 to 6.8 depending on its stage of maturity (Junior *et al*, 2009), with the presence of leaf detritus and other organic matter inside the bamboo, the pH might become acidic due to the curing and fermentation process, accelerated by rain. In fact, *Armigeres* was known to utilize the hollow internodes of living and dead bamboo as breeding sites due to the small opening at the internodes (1 mm to 2 mm in diameter) (Macdonald, 1960). An experiment conducted by Macdonald (1960) on *Ar. dolichocephalus* proved that it had the ability to squeeze through the opening of bamboo holes, once emerged.

Culex mosquitoes were absent in Sungai Penchala. This scenario could be due to the absence of breeding sites as the drainage system was not clogged and stagnant water was not found near the sampling site. Besides, the presence of large populations of *Armigeres* and *Aedes* dominating the area, caused difficulties for *Culex* to penetrate the area (Swapan and Ananda, 2010). Carrieri *et al* (2003) stated that it was challenging for a mosquito species to colonize a new habitat, depending on their ability to adapt to the new environmental conditions and to compete with the pre-existing species. In Taman Alam, the presence of *Culex* (20.85%) was within our expectation as this area was covered by stagnant water due to the choked drainage system and/or polluted water bodies such as those in septic tanks, puddles and water canals. Rohani *et al* (2008) reported that *Culex* larvae were mostly found breeding in polluted water bodies, as observed in this study. In addition, the water flow of the lake inside Taman Alam was controlled by a sluice gate, to allow the lake to be filled with sea water during high tide. According to Azzam *et al* (2010), *Culex* species are known to have the ability to exploit a wide variety of aquatic habitats for their development and survival, and can tolerate highly polluted aquatic environments and water with high salinity.

Seasonal abundance of mosquitoes

Results obtained from this study proved the correlation between selected mosquito species (*Ar. kesseli*, *Ar. subalbatus*, *Ae. albopictus*, and *Ae. butleri*) and the meteorological parameter rainfall, as reported by other researchers (Reuda *et al*, 1990; Patz *et al*, 1996; Jetten and Focks, 1997). However, since Malaysia is a tropical country, the abundance of any species depends more on the availability of breeding places than the season (Rozilawati *et al*, 2007).

Rainfall was one of the factors contributing to the outdoor-breeding mosquito population in Malaysia (Adzliyana, 2006). The wet seasons favored the breeding of mosquitoes and increased the transmission of mosquito-borne diseases (Okogun *et al*, 2003). The large number of mosquitoes captured in both study sites from December 2009 to January 2010 was possibly due to the increase of rainfall. A study performed by Rozilawati *et al* (2007) showed similar results which abundant *Aedes* eggs were found in ovitraps during the rainy season. Another local study by Rohani *et al* (2011) also demonstrated that rainfall played a significant role in increasing the mosquito population. Heavy rainfall increases mosquito breeding habitats. Furthermore, in both study sites, the shaded area and large density of vegetations contributed to the high number of adult mosquitoes captured during the wet season (high rainfall), as they provided nutrients for the larvae and more breeding habitats for the adults (Kittayapong, 2006).

To the best of our knowledge, this study is the first attempt to measure the seasonal abundance of *Ar. kesseli* and *Ar. subalbatus* in Malaysia. According to MacDonald (1960), *Armigeres* from the subgenus *Leicesteria* showed no direct relationship with rainfall. This is because firstly, *Leicesteria* depends on the presence of young bamboos and secondly, it depends on bamboo-boring beetle larvae. Since *Ar. kesseli* and *Ar. subalbatus* are more urbanized species, they may adapt in breeding places, similar to *Aedes* and *Culex*, such as artificial containers, coconut shells, and mostly polluted water (Pandian and Chandrashekaran, 1980). Concrete drainage with clear stagnant water in both places may also become a potential habitat for the breeding of this genus. Therefore, the availability of breeding sites with the help of rainfall increased the number of individuals of both species in forested and suburban areas. Other than that, high humidity (70%-85%) as recorded in both study sites prevented dehydration and desiccation of eggs.

In Taman Alam, as the mean rainfall dropped from February 2010 until September 2010, the mosquito population also decreased. However, the reduction in the number of *Armigeres* may also be caused by other factors. Predation by aquatic insects may have contributed to this reduction. As the site was in the forested area near the estuary of the Selangor river and a man-made lake, the presence of predators (tadpoles, copepods, dragonfly nymphs, and water beetles) may become a possible reason for the reduction in the *Armigeres* population, although in the current study, the number of aquatic predators was not quantified. Another possible factor contributing to the reduction in *Armigeres* was the fogging activities conducted by the Kuala Selangor District Council during or before the study period. According to Okogun (2003), once mosquitoes are established in an ecological zone, it is difficult to dislodge them. Even when the enabling environmental factor that supports the growth and development of the larvae and pupae is lacking, they tend to temporarily disappear and reappear once the environmental factors are re-established. Stivers (2005) reported on another possible factor, *ie*, the water in ditches and tree holes that are potential breeding sites of *Armigeres*, dried up quickly and soaked into the ground before the larvae could emerge as adults. Larvae of *Armigeres* require a much longer period to enclosed; therefore, the repetition of this type of cycle during low rainfall leads to the reduction in the *Armigeres* population in Taman Alam. Further research should be conducted to confirm the causes of reduction in the *Armigeres* population in Taman Alam after rainy season.

A significant association between *Aedes* density and rainfall was well documented by Thurman and Thurman (1955) (Thailand), Rao and Rajagopalan (1957) (India), Gould *et al* (1968) (Thailand), Rozilawati *et al* (2007) (Malaysia), and Rohani *et al* (2011) (Malaysia). *Ae. butleri* population in Taman Alam also showed a strong correlation with rainfall (r=0.85, p=0.00).

The surrounding suburban and forested areas as well as human activities may also have contributed to mosquito breeding sites. Plastic containers and cans were found scattered in both places. Plastic containers and cans that were indiscriminately discarded in the surrounding bushes made them widely available for *Ae*. *albopictus* breeding, especially in cool and shaded areas (Okogun *et al*, 2003). Fallen dried leaves in the forest may have contributed to the development of *Ae*. *albopictus* and *Ae. butleri* populations. *Ae. butleri* is known to inhabit swamps and brackish water. Since the secondary forest in Taman Alam is a former mangrove area, during the rainy season, the water becomes stagnant and produces many water puddles with brackish water. Thus, with such surroundings and the onset of rain, the abundance of *Ae. albopictus* and *Ae. butleri* is predictable.

In a temperate country, temperature and humidity also play an important role in determining the mosquito population. Barry and Steven (2001) reported that populations of *Ae. albopictus* occurring in regions with relatively high temperatures were likely to have high rates of population growth; relatively high temperatures increased the rate of spread of *Ae. albopictus* by enhancing colonization due to rapid population growth. Another experiment conducted by Monteiro *et al* (2007) showed that the best developing conditions for *Aedes* species occurred at 25-30°C and no individuals could reach the adult stage when the temperature reached 35°C. Lu *et al* (2009) stated that lower temperatures caused negative impact on the survival of adult and immature *Aedes* mosquitoes.

Although Sungai Penchala and Taman Alam had high populations of *Aedes* and *Armigeres* in the months with high humidity, no significant correlation was found ($p \geq 0.05$). As reported by Hales *et al* (2003), relative humidity influenced the longevity, mating dispersal, feeding behavior, and oviposition of the mosquitoes. In addition, mosquitoes generally survive longer and may disperse further at high humidity. Therefore, they have a greater chance of feeding on infected people and surviving in order to transmit the virus to other people.

According to Reiter (2001), the daily mean temperature in a dense forest can be as much as 10°C lower than in an adjacent open area. The relative humidity in a forested area may increase due to the lower evaporation, since sunlight may have difficulty in penetrating the canopy of the forest, especially during the rainy season (October–January). Therefore, the humidity is always high during the rainy season and these conditions are suitable for mosquitoes to breed and ensure the survival of vector populations.

The public health implications of various mosquito species identified in this study are numerous. For example, *Ae. butleri* is known to be a vector for Japanase encephilitis (JE); *Anopheles* is a malaria vector; and *Culex* and *Armigeres* are vectors for Bancroftian filariasis. Aside from health implications, nuisance, irritation, and annoyance due to their bites may reduce the interest and number of tourists who come to enjoy the scenery in Taman Alam. Since the seasonal fluctuation (rainfall) plays a role in determining mosquito abundance, several control measures can be implemented by the public (in Sungai Penchala), as they are close to their environment. The removal of unused containers, bush clearing around the houses, removing fallen leaves, and drainage clearing during the wet or dry season would help to reduce the vector population (Reiter *et al*, 1995; Rozilawati *et al*, 2007).

Moreover, local authorities should conduct adulticiding (spraying and fogging) and larvaciding, especially during the wet season. Other than that, the biological control agent *Bacillus thuringiensis* H-14 is one of the most effective and environmentally friendly agents. It is much safer than chemical insecticides and can be used in water holes, stagnant water in drains, tree holes, ditches, and almost anywhere that water collects (Van Essen and Hembree, 1980). Therefore, with cooperation between the public and local authorities, a successful vector control program to eliminate mosquitoes can be formulated (UNEP, ILO and WHO, 1999; Yap *et al*, 2003).

Whereas, in Taman Alam, the management should take the initiative to advise visitors before they enter Taman Alam in order to protect them from getting bitten by mosquitoes. The management should provide repellents or mosquito coils in the chalet. The public should dress appropriately, such as long-sleeved, loose-fitting, light-colored clothing with a tight weave, which help to reduce the skin exposed to mosquito bites.

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