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Biting behaviour of medically important mosquitoes (Diptera: Culicidae) in Peninsular Malaysia

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Abstract. Human-landing catch (HLC) technique was undertaken in nine selected study sites within Peninsular Malaysia to determine the biting cycle of *Aedes*, *Armigeres*, *Culex*, and *Mansonia* mosquitoes. HLC was conducted 24 hours on three different nights in a duration of one week at each study site. *Aedes albopictus* were found in all study sites with bimodal biting cycle, whereas the biting peak of *Aedes butleri* was recorded between 1600 and 1900 hr. For *Armigeres*, five study sites demonstrated similar biting peak hour (1900 – 2000 hr) for *Ar. kesseli* four study sites showed biting peak at 1800 – 1900 hr for *Ar. subalbatus*. *Culex quinquefasciatus* was collected from all study sites except in Sungai Penchala with its biting activity beginning from 1900 hr. Both *Mansonia annulifera* and *Mansonia uniformis* captured in two different study sites showed similar biting peaks (1500 – 1600 hr). It is recommended that vector control activities be carried out at dusk as almost all mosquito species captured started their biting activities at that time.

INTRODUCTION

Mosquitoes still remain as one of the most important public health concerns due to their capabilities in transmitting many vector-borne diseases. *Aedes aegypti* and *Ae. albopictus* are vectors of dengue and chikungunya in many countries including Malaysia, whereas *Ae. butleri* is known to be a vector for Japanese Encephalitis virus in Malaysia (Vythilingam *et al.*, 1994). Both *Armigeres kesseli* and *Ar. subalbatus* commonly found in Malaysia (Buckley *et al.*, 1956). *Ar. subalbatus* are known to transmit Brugian filariasis (Wharton, 1962). As for *Culex* mosquitoes, even though *Culex quinquefasciatus* acts more as an urban nuisance mosquito (Lee *et al.*, 1997), it has potency in transmitting urban bancroftian filariasis in Malaysia (Nazni *et al.*, 2005). *Mansonia uniformis* is one of the important vectors of Brugian filariasis in Malaysia (Vythilingam *et al.*, 1992).

Various vector control measures are applied in order to suppress mosquito populations. Because of that, knowledge on mosquito biting rates (MBR) is necessary so that appropriate vector control strategies could be planned. Mosquito biting rates (MBR) refers to the density of mosquitoes involved in biting. Information on biting activities of vectors facilitates the selection

of personal protection measures that would prevent human-mosquito contact (Abu Hassan *et al.*, 2001; Korgaonkar *et al.*, 2012).

Numerous studies on the biting pattern of Malaysian mosquitoes have been reported to date. For instance, Macdonald (1960) reported on the biting activity of *Armigeres* (*Leicesteria*) in Ulu Gombak, Selangor, whereas Cheong *et al.* (1988) described on biting activities of several species of the genera *Aedes*, *Culex* and *Armigeres* in Sabah. Later in 2011, Wan-Najdah *et al.* studied the periodicity of five species of the genera *Anopheles*, *Aedes*, *Armigeres* and *Culex* at an aborigine village which was reported to have highest incidence rate of malaria cases in Peninsular Malaysia.

Biting activity is crucial to be examined in order to understand biting cycles of the vector species (Rohani *et al.*, 2008). With equal numbers of catches ranging over the same catch points being performed for an hour, a preliminary interpretation of the mosquito biting patterns collected in the chosen areas could be obtained (Amerasinghe, 1982). Thus, this study was undertaken to investigate and re-examine the biting cycle of four predominant mosquitoes genera (*Aedes*, *Armigeres*, *Culex*, *Mansonia*) collected from different sites across Peninsular Malaysia.

MATERIALS AND METHODS

Study sites

Nine study sites within Peninsular Malaysia were chosen randomly for this study. The ecological description of the study sites is given in Table 1.

Adult mosquitoes collection

Mosquitoes were collected by human-landing catch (HLC) technique (Haddow, 1954; Haddow, 1960; Macdonald, 1960) using 50 x 19 mm glass vials that were subsequently plugged with cotton. This standard technique is able to provide reliable and consistent results in determining the mosquito biting rate (Overgaard *et al.*, 2012). HLC in all study sites were carried out on various dates between 16 July 2009 and 20 September 2009 which was during dry season. HLC was conducted in all study sites for 24 hours (0700-0700) which was divided into 2 shifts (0700-1900 and 1900-0700). During each shift, 3 people who acted as human baits sat near the mosquito's potential breeding or resting sites such as shrubs and water puddles. In order to avoid bias, same well-trained and non-smoker volunteers aged between 23-25 years old were involved as human baits throughout this study. Informed consent forms were disseminated and signed by the collectors prior to the conduct of HLC. Captured mosquitoes were identified and segregated according to species, date and time. HLC was performed in triplicate on different nights within a week of duration.

For identification and taxonomy purposes, cross reference was done with mosquito collections from the Institute for Medical Research (IMR), Kuala Lumpur, Peninsular Malaysia as well as using a pictorial key to identify mosquitoes (Choeng & Mahadevan, 1970) and the Keys of Triplehorn and Johnson (2005).

Data analysis

The mosquito biting rate (MBR) was determined using the formula below:

$$\text{MBR} = \frac{\text{Total number of collected mosquitoes of a particular species per hour}}{\text{Total number of human baits per hour (3 people)}}$$

RESULTS AND DISCUSSION

Across nine study sites, two species of *Aedes* were captured which were *Ae. albopictus* and *Ae. butleri*. *Aedes albopictus* was present in all study sites, while *Ae. butleri* were recorded in almost all study sites except in Sungai Penchala, University of Malaya and Taman Kubang Pasu.

Table 2 shows biting peaks of all mosquito species collected in different study sites. Generally, the biting peak of *Ae. albopictus* in these study sites was from 1700 hr to 1900 hr. Taman Alam and Carey Island showed the highest and the lowest

Table 1. Description of nine selected study areas for mosquito sampling

Region	State	District	Study Sites	Coordinates	Description
North	Kedah	Kubang Pasu	Taman Kubang Pasu (TKP)	6° 16' 00" N, 100° 25' 30.13" E	• A residential area located at the outskirts of the city consisting of bungalows, semi-detached houses and terrace houses. • Its drainage system is properly built and the environment is generally cleaned. • Some natural and artificial vegetation and shrubs could be found within the area.
West	Selangor	Petaling	Sungai Buloh Dua (SBD)	3° 14' 22.01" N, 101° 18' 51.39" E	• An area with a high vegetation of *Orthosiphon aristatus* (misai kucing) plants. • There are also few oil palm plantations, small swamps and small bushes nearby. • Piles of scrap metals were observed.
West	Selangor	Kuala Selangor	Taman Alam (TA)	3°20'24.69"N, 101°14'33.87"E	• A recreational park. • It covers approximately 234 acres of mangroves and mudflats. • Consists of 497acres of secondary forest area. • The area is dominated by strangling figs and other coastal trees like the *Cordia dichtama* as well as the mangrove ferns.
West	Selangor	Klang	Carey Island (CI)	2° 55' 60" N, 101° 24' 0 E	• The building of Mangrove Research Centre (MRC) was first built as a platform for research on mangrove ecosystem and coastal zone management in Malaysia. • MRC is surrounded by a small swamps, an open golf course, and an oil palm mill. • A nursery was built behind MRC to grow mangrove seedlings in coir logs.
Center	Selangor	Gombak	Ulu Gombak Forest Reserve (UGFR)	3° 17' 57.86" N, 101° 47' 00.78" E	• The area covers 120-hectares of secondary and primary forest. • Its flora and fauna are extensively studied and documented throughout the site's 40-year history. • High vegetation.
Center	Kuala Lumpur	Lembah Pantai	University of Malaya (UM)	3° 7' 15" N, 101° 40' 12" E	• An area within a university campus that consists of premises of administration buildings, shops and mini orchards. • Small bushes, pandanus plants and trees from palmae family could be found covering the ground. • There is a greenhouse planted with many small ornamented flowers such as hibiscus, spider lily and also herbs tree such as garlic for experimental use.
Center	Kuala Lumpur	Segambut	Sungai Penchala (SP)	3° 10' 0" N, 101° 38' 0" E	• An unplanned housing area. • Bungalow houses are scattered within the area. • It is surrounded by a dense vegetation and a durian orchard.
South	Johor	Muar	Kg. Parit Unas (KPU)	2° 02' 59.2" N, 102° 34' 15.10"E	• An area that is surrounded with high densities of shrubs and other small trees. • Poor drainage system. • Houses are scattered within the area. • An illegal rubbish dumping area created by residents was observed.
East	Pahang	Jerantut	Felda Sungai Tekam (FST)	3°44'39.82"N , 102°32'30.78"E	• One of the FELDA oil palm cultivation research areas. • The workers' quarters are made from wooden walls and cement flooring. • A well-planned housing area with a good drainage system. • Small bushes and shrubs are found nearby.

Table 2. Biting peaks of mosquitoes captured from selected study sites in Peninsular Malaysia

Study Sites	*Aedes*				*Armigeres*					
	Ae. albopictus		*Ae. butleri*		*Ar. kesseli*		*Ar. subalbatus*		*Ar. flavus*	
	Time	MBR ± S.D.	Time	MBR ± S.D.	Time	MBR ± S.D.	Time	MBR ± S.D.	Time	MBR ± S.D.
SP	1700-1800	14.67 ± 3.06	N.A.	N.A.	1900-2000	27.67 ± 2.52	1900-2000	14.00 ± 4.36	N.A.	N.A.
UM	1700-1800	12.33 ± 4.04	N.A.	N.A.	2000-2100	3.67 ± 2.08	N.A.	N.A.	N.A.	N.A.
CI	1900-2000	2.67 ± 0.58	2000-2100	2.33 ± 0.58	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SBD	1700-1800	25.33 ± 5.51	1700-1800	10.00 ± 2.00	1900-2000	22.00 ± 5.00	1900-2000	17.67 ± 3.51	N.A.	N.A.
UGFR	1800-1900	14.67 ± 5.51	1800-1900	6.33 ± 0.58	1800-1900	17.67 ± 2.52	1800-1900	14.00 ± 3.61	1700-1800	1.67 ± 1.15
TA	1700-1800	29.00 ± 3.61	1800-1900	18.67 ± 5.51	1800-1900	24.33 ± 4.04	1800-1900	5.33 ± 3.21	N.A.	N.A.
TKP	1800-1900	22.67 ± 2.08	N.A.	N.A.	1800-1900	4.00 ± 1.00	N.A.	N.A.	N.A.	N.A.
KPU	1700-1800	13.00 ± 1.00	1800-1900	2.33 ± 2.08	1800-1900	6.00 ± 3.61	1800-1900	23.00 ± 2.00	N.A.	N.A.
FST	1800-1900	13.33 ± 2.52	1500-1600	0.33 ± 0.58	1800-1900	0.33 ± 0.58	1800-1900	0.67 ± 1.15	N.A.	N.A.

Study Sites	*Culex*									
	Cx. quinquefasciatus		*Cx. vishnui*		*Cx. gelidus*		*Cx. fuscocephala*		*Cx. tritaeniorhynchus*	
	Time	MBR ± S.D.	Time	MBR ± S.D.	Time	MBR ± S.D.	Time	MBR ± S.D.	Time	MBR ± S.D.
SP	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
UM	2000-2100	9.33 ± 3.21	2000-2100	1.67 ± 0.58	N.A.	N.A.	2000-2100	6.33 ± 1.53	N.A.	N.A.
CI	2100-2200	1.33 ± 0.58	2000-2100	51.33 ± 12.66	2100-2200	9.00 ± 1.00	N.A.	N.A.	N.A.	N.A.
SBD	2100-2200	8.33 ± 1.53	2100-2200	32.33 ± 4.93	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
UGFR	2000-2100	10.33 ± 3.79	N.A.	N.A.	2000-2100	11.33 ± 3.51	N.A.	N.A.	N.A.	N.A.
TA	2000-2100	0.33 ± 0.58	2100-2200	15.67 ± 4.04	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
TKP	2100-2200	31.67 ± 9.07	2100-2200	15.67 ± 3.21	2100-2200	24.67 ± 4.51	N.A.	N.A.	2100-2200	6.67 ± 1.53
KPU	2100-2200	16.67 ± 1.15	2100-2200	4.67 ± 0.58	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
FST	2000-2100	4.33 ± 1.15	2100-2200	3.67 ± 0.58	2000-2100	0.33 ± 0.58	N.A.	N.A.	N.A.	N.A.

Study Sites	*Mansonia*			
	Ma. annulifera		*Ma. uniformis*	
	Time	MBR ± S.D.	Time	MBR ± S.D.
SP	N.A.	N.A.	N.A.	N.A.
UM	N.A.	N.A.	N.A.	N.A.
CI	1500-1600	1.33 ± 0.58	N.A.	N.A.
SBD	N.A.	N.A.	1500-1600	1.00 ± 1.00
UGFR	N.A.	N.A.	N.A.	N.A.
TA	N.A.	N.A.	N.A.	N.A.
TKP	N.A.	N.A.	N.A.	N.A.
KPU	N.A.	N.A.	N.A.	N.A.
FST	N.A.	N.A.	N.A.	N.A.

MBR = Mosquito biting rate. S.D. = Standard Deviation. N.A. = Not Available

number of mosquito/man/hour for *Ae. albopictus*. Meanwhile, Taman Alam demonstrated highest number of mosquito/man/hour for *Ae. butleri* but the lowest peak for the same species was recorded in Felda Sungai Tekam.

As illustrated in Figure 1, the biting cycle of *Ae. albopictus* was bimodal; a minor peak occurred in the morning at 0800 – 1000 hr, while a major peak was demonstrated between 1700 hr and 1900 hr. Highest catches were recorded in Taman Alam with two peaks at 0900 – 1000 hr and 1700 – 1800 hr which were similar to findings by Xue & Barnard (1996). Marques & Gomes (1997) also reported on biting activity of *Ae. albopictus* which took place during the day with the peak time of 0600 – 0700 hr, 1300 – 1400 hr and the highest at 1600 – 1700 hr. In 2014, Chen *et al.* showed on later hours of biting peaks for *Ae. albopictus* which were at 0700 – 0900 hr and 1700 – 1900 hr. Wan-Najdah *et al.* (2011) demonstrated much more later peak hour of biting activity for *Ae. albopictus* which was at 1900 – 2000 hr. Other than that, there were biting activities during day time but no biting activities were recorded after 2300 hr in all study sites.

Aedes albopictus is known as a day time feeder but it could still be captured after dusk depending on the availability of blood meal sources (Basio & Santos-Basio, 1974). Cheong *et al.* (1988) reported a different pattern of biting activity demonstrated by *Ae. albopictus* captured in Sabah where both the major peak and the minor peak were recorded at early morning (0600 – 0800 hr) and at dusk (1800 – 2000 hr), respectively. Some smaller peaks were also noticed at night. Oh (2007) also reported that *Ae. albopictus* is a day time feeder but no regular biting peak was obtained from her studies.

Meanwhile, the peak of *Aedes butleri* biting activity was recorded between 1600 and 1900 hr and no biting activity was recorded between 2300 – 1000 hr (Figure 2). Highest biting rate was recorded in Taman Alam during 1800 – 1900 hr. A field test on the repellent diethyltoluamide (DEET) done by Traub & Elisberg (1962) in a nipah palm-mangrove swamp in Selangor showed that *Ae. butleri* biting activity was at peak at a later time (1845 – 2000 hr). In contrast, Cheong *et al.* (1988) reported that similar species in Bengkoka, Sabah attacked humans for 24 hours with two main peaks at 0700 – 1000 hr and 1600 – 1900 hr.

On the other hand, none of *Armigeres* species was found in Carey Island (Table 2). Five study sites showed similar biting peak

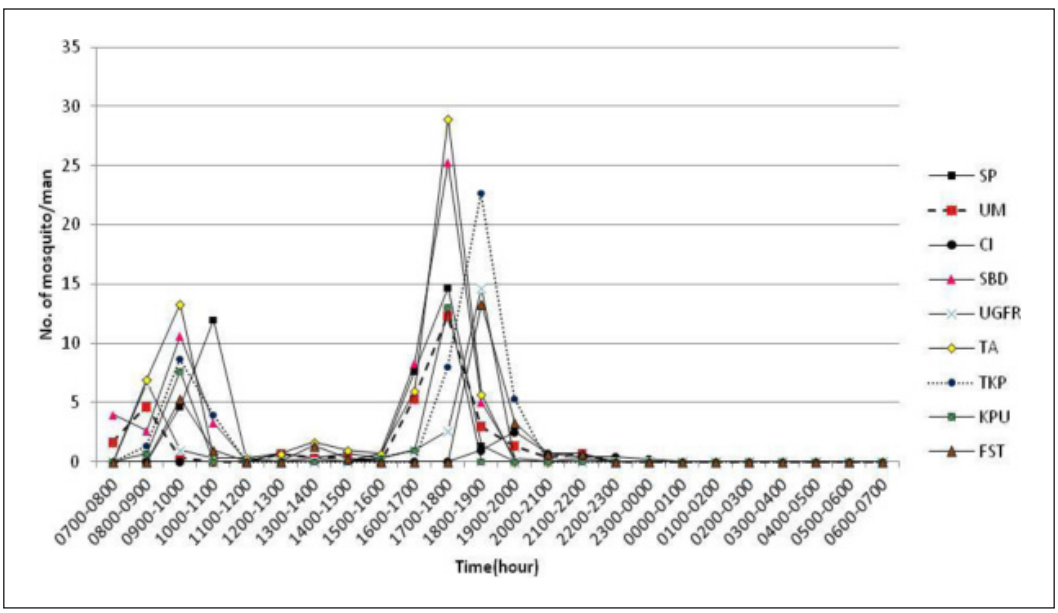

Figure 1. Biting behaviour of *Ae. albopictus* captured from nine study sites in Peninsular Malaysia.

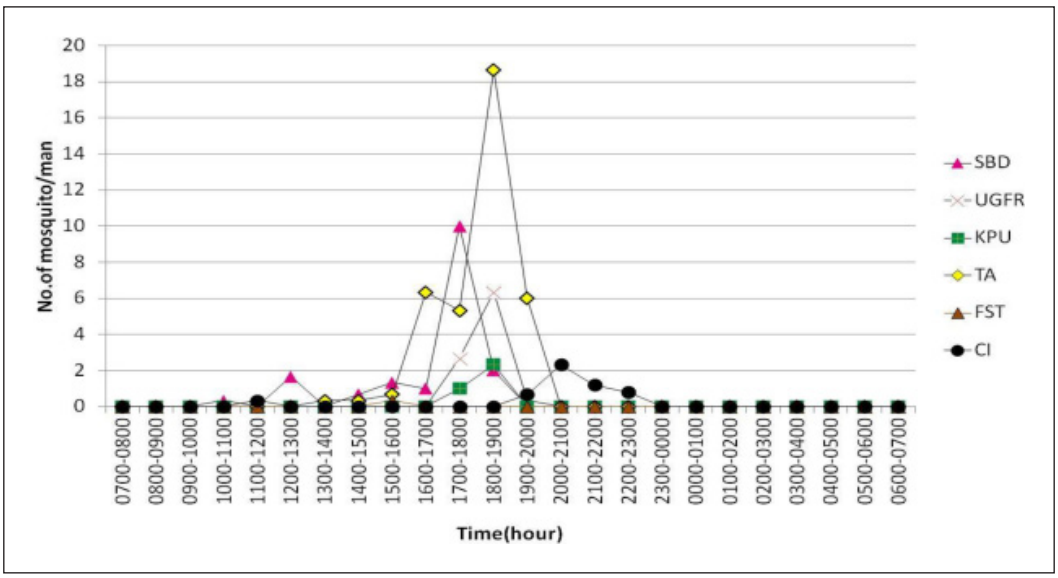

Figure 2. Biting behaviour of *Ae. butleri* captured from six study sites in Peninsular Malaysia.

hour (1900 – 2000 hr) for *Ar. kesseli* but the highest number of mosquito/man/hour was recorded in Sungai Penchala at 1900 – 2000 hr. Four study sites demonstrated similar biting peak hour (1800 – 1900 hr) of *Ar. subalbatus* with the highest number of mosquito/man/hour was noticed in Kg. Parit Unas. Nevertheless, *Ar. flavus* was found only in Ulu Gombak Forest Reserve (UGFR).

Armigeres is reported to be crepuscular that exhibits a small peak at dawn and a larger peak at dusk (Pandian & Chandrashekaran, 1980). Haddow *et al.* (1968) stated that crepuscular activity is closely related to the rate of light change at sunset and sunrise.

The presence of *Ar. kesseli* was recorded in all study sites except in Carey Island. Its biting cycle showed two peaks; a small morning peak at 0700 hr – 0900 hr and a higher peak at dusk (1800 hr – 2000 hr) (Figure 3). The highest biting activity was recorded in Sungai Penchala with two biting peaks at 0700 hr - 0800 hr and 1900 hr – 2000 hr. Its biting cycle was almost similar to *Ar. subalbatus*. However, *Ar. flavus* only showed one biting peak in the evening (1800 hr – 1900 hr).

Biting peak recorded for *Ar. subalbatus* was different from other mosquito (Figure 4). *Ar. subalbatus* collected in Sungai Buloh Dua showed the highest biting peak in the morning from 0700 hr – 0800 hr which was a bit earlier than other study sites. However, the biting peak in the evening was recorded highest in Kg. Parit Unas from 1800 hr – 1900 hr. Results of biting pattern of *Ar. subalbatus* found in six study sites were almost similar to the study done by Pandian & Chandrashekaran (1980). Results showed that the landing and biting of *Ar. subalbatus* during non-peak hours was very low and the pattern resembled the crepuscular biting pattern exhibited by the *Aedes* species except that their peak hours were not exactly the same.

Only one biting peak was recorded for *Ar. flavus* in UGFR which was at 1800 hr – 1900 hr. According to Macdonald (1960), *Ar. flavus* bit principally by day time and showed no clear evening peak and quite active after midday until dusk. Insufficient number of individual samples in this study could be the reason of obtaining different results from the previous study. In addition, *Ar. flavus* was known as a forest mosquito and its natural feeding habits may differ from the urban mosquitoes which prefer human blood (Macdonald, 1960). There are many other forest mammals that are probably the major blood sources of this mosquito species.

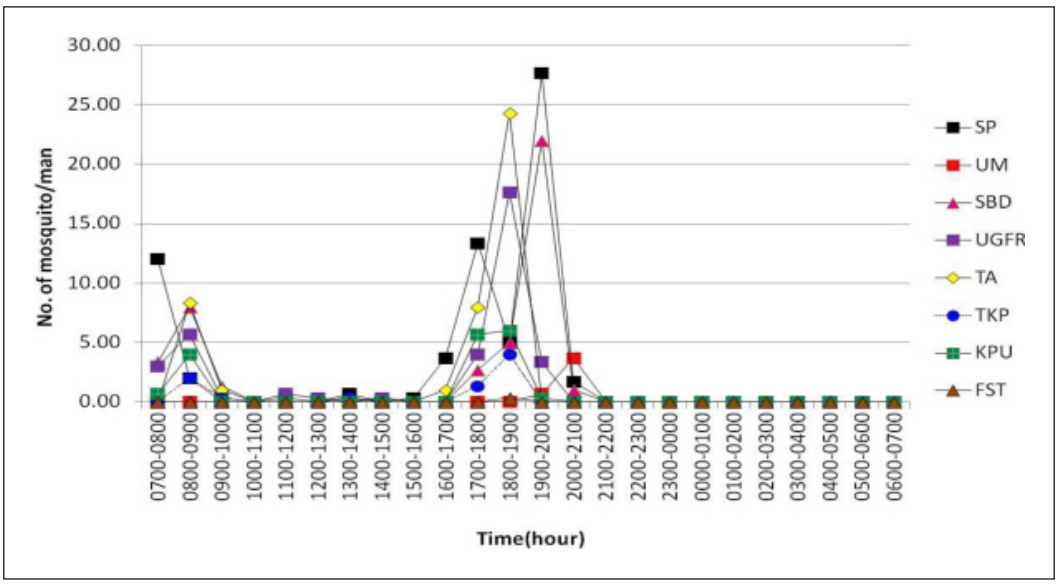

Figure 3. Biting behaviour of *Ar. kesseli* captured from eight study sites in Peninsular Malaysia.

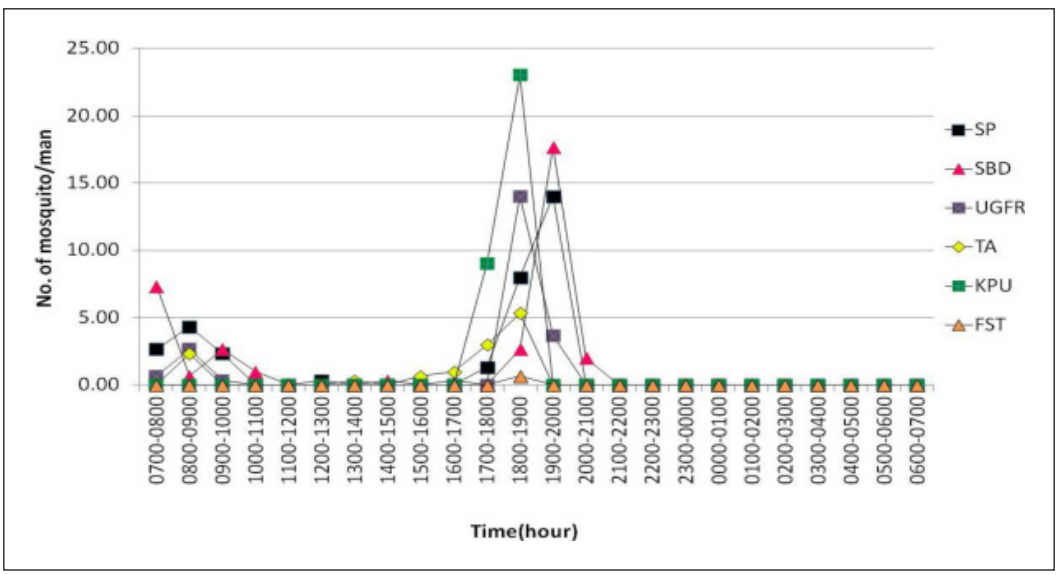

Figure 4. Biting behaviour of *Ar. subalbatus* captured from six study sites in Peninsular Malaysia.

Five species of *Culex* were obtained from all study sites. No *Culex* were captured in Sungai Penchala. In general, biting peaks for *Culex* started from 2000 hr until 2200 hr. Taman Kubang Pasu demonstrated highest number of mosquito/man/hour for both *Cx. quinquefasciatus* and *Cx. gelidus* during the same biting peak hour. Meanwhile, the highest number of mosquito/man/hour for *Cx. vishnui* was recorded in Sungai Buloh Dua at 2100 – 2200 hr as well. *Cx. fuscocephala* was captured only in University of Malaya with biting peak at 2000 – 2100 hr while *Cx. tritaeniorhynchus* was found only in Taman Kubang Pasu with biting peak at 2100 – 2200 hr.

Biting activities of certain *Culex* mosquitoes such as *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus* are known to be unimodal nocturnal (Reuben, 1971; Vythilingam *et al.*, 1996). *Culex quinquefasciatus* was obtained in all study sites except in Sungai Penchala. Its biting activity started from 1900 hr and achieved the peak at 2000 hr – 2200 hr. The highest catch was recorded in Taman Kubang Pasu at 2100 hr – 2200 hr (Figure 5). Samarawickrema (1967) recorded on a prolonged peak biting period that started at an hour before midnight and lasted for three hours. Similar result was recorded by Aigbodion & Emiebor (2008) where the biting peak of *Cx. quinquefasciatus* was demonstrated at 0000 hr – 0200 hr.

Biting activity of *Cx. vishnui* was recorded throughout the night (1900 hr – 0700 hr) and a peak was recorded at 2000 hr – 2200 hr (Figure 6). The highest catch was recorded in Carey Island at 2000 hr – 2100 hr. This result supported the fact by Wharton (1951) who stated that *Cx. vishnui* biting rate before midnight was higher than after midnight. No *Cx. vishnui* was obtained in the day time (0700 hr – 1900 hr) at any study sites.

Culex gelidus was found in four study sites, namely Ulu Gombak Forest Reserve, Taman Kubang Pasu, Carey Island and Felda Sungai Tekam. Its biting activity was recorded from 1900 hr and the biting peak was reached at 2000 hr – 2200 hr (Figure 7). The highest catch was recorded in Taman Kubang Pasu with 24.67 ± 4.51 mosquitoes/man/hour at 2100 hr – 2200 hr. In other local study conducted by Vythilingam *et al.* (1995), both *Cx. vishnui* and *Cx. gelidus* in Sabak Bernam, Selangor bit all the night and reached the peak of their biting activities at 1900 – 2000 hr.

Culex tritaeniorhynchus was found only in Taman Kubang Pasu with the biting peak at 2100 hr – 2200 hr (6.67 ± 1.53 mosquitoes/man/hour) and no biting activity was recorded during day time and after 2200 hr. Both *Cx. gelidus* and *Cx. tritaeniorhynchus* prefer to bite pig and cow compared to man (Mwandawiro *et al.*, 1999; Mwandawiro *et al.*, 2000). As such, highest numbers of *Cx. tritaeniorhynchus* biting pigs were observed in the rice fields in Sarawak (Hill, 1970).

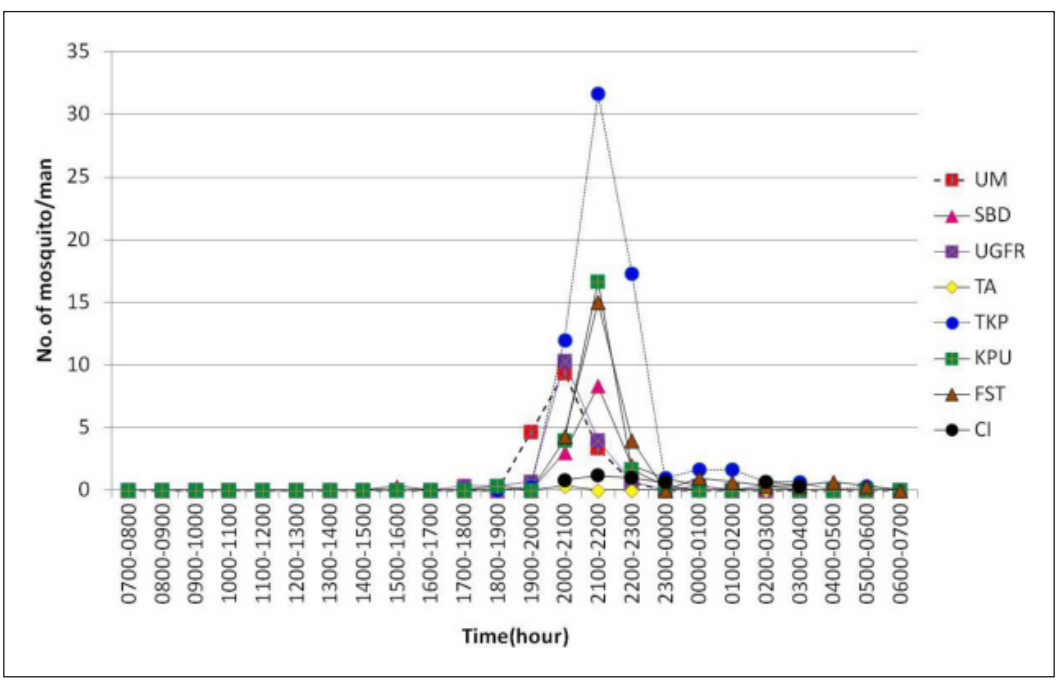

Figure 5. Biting behaviour of *Cx. quinquefasciatus* captured from eight study sites in Peninsular Malaysia.

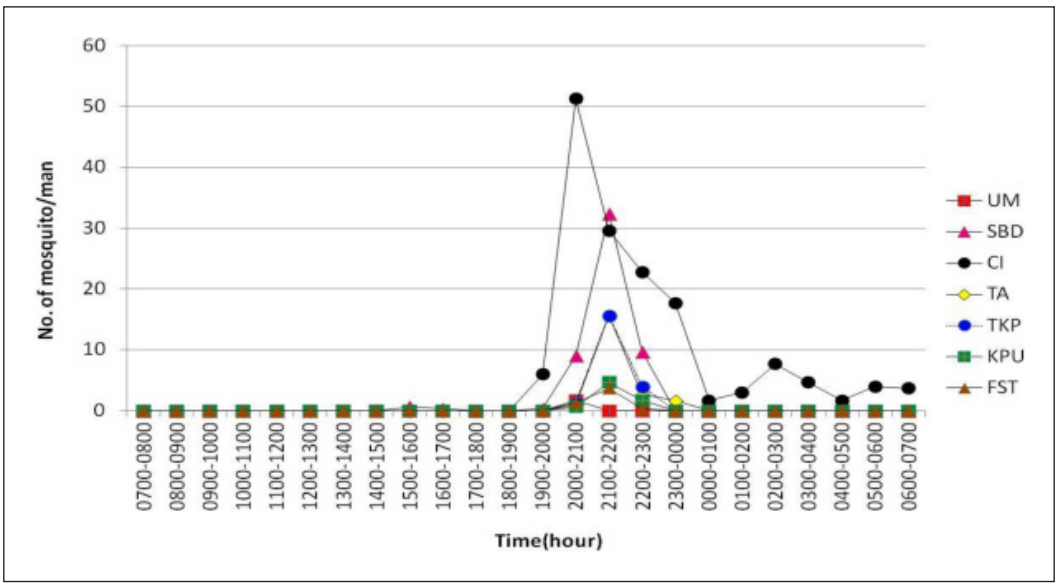

Figure 6. Biting behaviour of *Cx. vishnui* captured from seven study sites in Peninsular Malaysia.

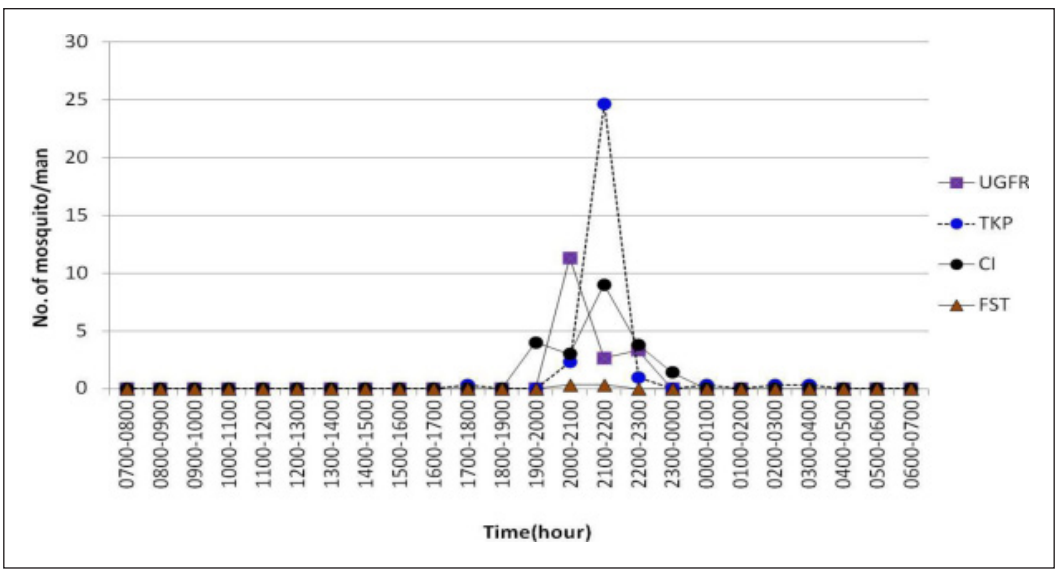

Figure 7. Biting behaviour of *Cx. gelidus* captured from four study sites in Peninsular Malaysia.

Hence, in this study, they could probably have represented only a small number of populations since the study area was not a farm or an agricultural area.

Small number of *Cx. fuscocephala* was found only in University of Malaya with a maximum density recorded between 2000 hr and 2100 hr (6.33 ± 1.53 mosquitoes/man/hour). Amerasinghe & Munasingha (1994) reported the biting activity of *Cx. fuscocephala* which took place during late evening (1800 hr – 1900 hr) or at early morning (0400 hr – 0500 hr). The information of *Cx. fuscocephala* and *Cx. tritaeniorhynchus* biting behaviours in this study were not convincing due to the

insufficient number of specimens obtained from study sites.

In addition, *Ma. annulifera* was found only in Carey Island while *Ma. uniformis* was detected only in Sungai Buloh Dua. Interestingly, both species at different study sites however share biting peak hour at 1500 – 1600 hr.

Mansonia tends to be exophagic and exophilic. Biting occurs mostly during the day. They are predominantly zoophilic and, although primarily exophagic, they readily enter houses to feed on human (Bockarie *et al.*, 2009). The biting activity of *Ma. annulifera* was recorded from 1200 hr to 1700 hr. The peak was recorded at 1500 hr – 1600 hr (1.33 ± 0.58 mosquitoes/man/hour). In contrast, Nagpal & Sharma (1983) reported that biting peak of *Ma. annulifera* found in Andaman Island was at 1730 hr – 1830 hr and its biting activity continued until 2030 hr.

On the other hand, biting activity of *Ma. uniformis* was recorded only in Carey Island from 1300 hr to 2200 hr. Biting peak was observed at 1500 hr – 1600 hr with 1.00 ± 1.00 mosquito/man/hour. According to Standfast (1967), *Ma. uniformis* could be captured during the day time, mostly in shaded locality. However, a unimodal biting pattern of *Ma. uniformis* which reached the peak at 2 – 4 hr after sunset was reported in Sri Lanka (Amerasinghe & Indrajith, 1995).

Based on this study, biting pattern of each mosquito species varied widely. Differences in results could be due to the level of adaptation displayed by each species in different areas and environment. However, most of mosquito species typically started to hunt for blood meal shortly before sunset (1800 hr) and usually reach their peaks during the succeeding one to three hours at night (2000 hr). From HLC conducted throughout this study, collectors influenced the presence of mosquitoes. In fact, scientists have been reporting on incidences where mosquitoes bite some people more frequently than others and it is likely to be mediated by differences in body odours (Logan, 2008) as well as carbon dioxide (CO_2) from vertebrate breath (Sukumaran *et al.*, 2016), human body heat (Corfas & Vosshall, 2015) and visual cues (Hawkes & Gibson, 2016).

In general, *Aedes* and *Amigeres* could be captured throughout the day and night (until 2100 hr) but their biting peaks were observed at early morning (0800 – 1000 hr) and late evening (1700 – 2000 hr), while *Culex* was known as a nocturnal biter with biting peak varies between 2000 hr and 2300 hr. Even though *Mansonia* demonstrated biting peaks at around 1300 – 1600 hr, they could still be found at sunset. Hence, this study suggests vector control programmes such as fogging or insecticides spraying in all study sites to be conducted at dusk since biting activities of almost all mosquito species captured in these study sites were noticed at that time. Larviciding and elimination of aquatic plants are also beneficial to combat mosquito larval populations of different species such as *Mansonia* sp. Other personal protection measures such as the use of impregnated nets and mosquito mats could also be applied concurrently to decrease the possibility of being bitten by these mosquitoes.

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