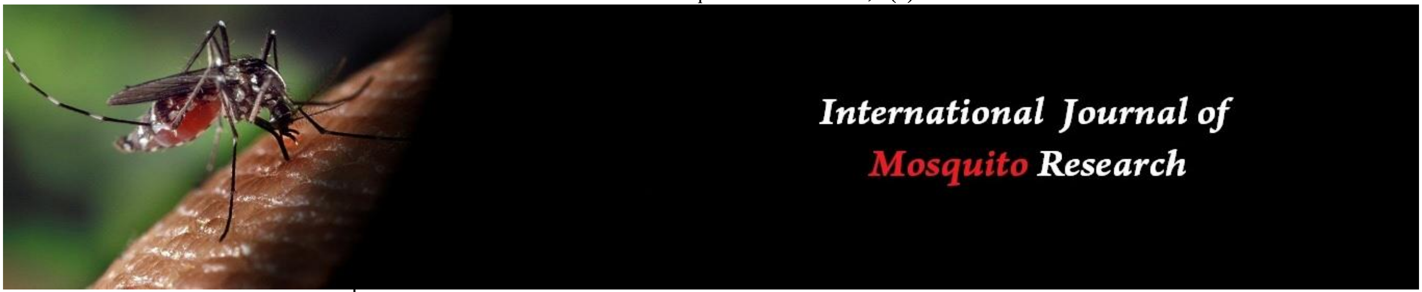
International Journal of Mosquito Research 2019; 6(1): 50-54



ISSN: 2348-5906
CODEN: IJMRK2
IJMR 2019; 6(1): 50-54

Received: 21-11-2018
Accepted: 25-12-2018

TN Saffawati T Ismail
School of Biological Sciences, Universiti Sains Malaysia, Minden, Penang, Malaysia

Nur Faeza A Kassim
a) School of Biological Sciences, Universiti Sains Malaysia, Minden, Penang, Malaysia
b) Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia, Minden, Penang, Malaysia

Azimah Ab. Rahman
School of Humanities, Universiti Sains Malaysia, Minden, Penang, Malaysia

Suhaila Ab. Hamid
School of Biological Sciences, Universiti Sains Malaysia, Minden, Penang, Malaysia

Khairun Yahya
School of Biological Sciences, Universiti Sains Malaysia, Minden, Penang, Malaysia

Cameron E Webb
a) Medical Entomology, NSW Health Pathology, Level 3 ICPMR, Westmead Hospital, Westmead, NSW, Australia.
b) Marie Bashir Institute of Infectious Diseases and Biosecurity, University of Sydney, Sydney, NSW, Australia

Correspondence
Nur Faeza A Kassim
a) School of Biological Sciences, Universiti Sains Malaysia, Minden, Penang, Malaysia
b) Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia, Minden, Penang, Malaysia

The application of geographic information system (GIS) to assess the population abundance of *Aedes albopictus* (Skuse) in mangrove forests of Penang, Malaysia

TN Saffawati, T Ismail, Nur Faeza A Kassim, Azimah Ab. Rahman, Suhaila Ab. Hamid, Khairun Yahya and Cameron E Webb

Abstract
Mangrove forests in Malaysia represent ecosystems containing a variety of flora and fauna species. Mosquitoes are common in these habitats and known vectors of mosquito-borne pathogens, an understanding of the abundance and distribution of mosquitoes in mangrove forests assists the assessment of potential disease outbreak. The mangrove environments are physically challenging to survey due to extensive muddy flats and frequent tidal inundation so limits the opportunities to study the mosquito populations. The focus of the study is to assess the risk of mosquito borne pathogen transmission at Pulau Betong, Balik Pulau, Penang by mapping the distribution of known vector species found in mangrove habitats by using ovitrap data incorporated into Geographical Information System (GIS) analysis. The study found that over a six month period, the activity of *Aedes albopictus*, peaked in August and October before a drastically droping in early November due to the onset of the dry season.

Keywords: Mosquito, *Aedes albopictus*, mangrove, GIS

1. Introduction
Malaysia contains some of the largest mangrove habitats in the Asia Pacific region. The variability and ecosystem richness of mangrove forests have provided Malaysia with ample resources for sustainability and developments. However, mangrove forests are under threat due to urbanisation [1] but may also increase in the future as a strategy to mitigate the impacts of sea level rise [2]. As a consequence, consideration must be given to the way these environments are managed in the future to minimise any public health risk.
Mangrove forests represent a unique ecological niche that provides habitat for variety of fauna species, including mosquitoes that may pose pest and public health risks. Previous studies proved that mosquitoes which are pest and potential vector of pathogen are part of mangrove ecosystems [3, 4]. While these habitats often provide habitat for species associated with ground pools filled by tide or rainfall, there are also habitats within tree holes, as well as accumulated rubbish (e.g. plastic containers that may be filled by rainfall) that may be used by species not typically associated with such habitats. The mosquitos species such as *Anopheles* and *Aedes* collected in mangrove forests past years showed a potential risk of mosquito borne diseases outbreak [5, 6] such as Dengue and Malaria.
An accurate assessment of public health risk requires more detailed information on local mosquitoes. However, there is a paucity of information currently available on mosquito species associated with Malaysia's mangrove ecosystems, restricting the implementation of mosquito-borne disease risk management strategies. The inaccessibility of the inner zone of extensive mangrove forests, due to fluctuating tides and soft sediments, further restricts the ability to comprehensively assess mosquito productivity. Due to these factors, the implementation of Geographical Information System (GIS) to study the population abundance of container-inhabiting mosquitoes associated with mangrove habitats was assessed. Ovitrap surveillance and Geographical Information System (GIS) are integrated systems develop to study, determine and predicts the course of mosquito abundance over spatial and temporal distribution.

Using ovitrap surveillance as a measure to detect and monitoring *Aedes* population at low density is highly sensitive, efficient and environment-friendly [7].

2. Materials and Methods
2.1 Study site
Pulau Betong, Balik Pulau located at the southwest corner of Penang Island. The geographical coordinate of Pulau Betong is 5.307328, 100.194558. Pulau Betong is a small village settlement developed at the estuary of Sungai Pulau Betong, with the closest major urban center being Georgetown. The study areas are impacted by human activity with the local environment characterized by evidence of artificial mosquito habitats including water-holding containers (e.g. bottles, cans, plastic containers and discarded tires) as well as natural habitats (e.g. tree holes, crab holes and water-filled ground pools). This research was conducted from July 2015 to December 2015.

2.2 Larvae collection
The focus of this study, mosquito eggs and larvae were collected using standard CDC modified oviposition traps (Ovitrap) with a total of 30 ovitraps were deployed randomly in the study sites (figure 1). Individual ovitraps were placed in either partial or total shade to avoid from direct sunlight and heavy rain that may cause water spillage. Larval collection and ovitrap maintenance was carried out at 5-days intervals over the course of the study. The medium in the ovitraps and the hardboard paddles were transferred to plastic containers then labeled and transported to the laboratory for species identification. Ovitraps were replaced with a clean set for the next 5 days and repeated for the course of 6 months sampling. The samples were identified according to morphological characteristics of mosquitoes based on mosquito identification keys by Jeffery *et al.* [8] and Rattanarithikul [9].

Fig 1: Ovitrap deployed in mangrove forest in Sungai Burung, Balik Pulau.

2.3 Statistical analysis and geographical information system (GIS)
Positive Ovitrap Index (POI) and mean larvae per trap revised from Serpa *et al.* [10] were used to measure the infestation of *Ae. albopictus* population in the study area meanwhile Pearson's correlation test was used to determine the relationship between the number of traps containing larvae intensity. The formula used during the experimentation includes:

$$\text{Positive Ovitrap Index (POI)} = \frac{\text{Number of ovitraps positive for oviposition}}{\text{Total number of ovitraps}} \times 100$$

$$\text{Mean larvae per trap (MLT)} = \frac{\text{Number of } \textit{Ae. albopictus} \text{ collected per ovitrap}}{\text{Total mosquito larvae collected per ovitrap}}$$

ArcGIS 10.3 software was used to monitor, analyze and constructed the distribution and population density of mosquitoes in mangrove forest by generating the spatial maps of the areas that was then analyzed using spatial analysis tool, Kernel density and inverse distance weighted (IDW) interpolation.

3. Results and Discussion
The habitat preferences of mosquitoes has always become one of the important study to understand the effect or adaptation of certain mosquito species which will provide the higher longevity to their species. At most times, mosquitoes were classified to urban, pre-urban and rural or forests mosquitoes depending on their abundance and ability to survive to a certain environmental conditions. *Aedes albopictus* were originally a forest species which has adapted to urban areas, due to the prevalence of habitats represented by water-holding containers and its host feeding preferences of humans [3, 11]. The accumulation of artificial water-holding containers present in coastal areas, where tides drive accumulation of floating debris and rubbish [12], has the potential to enhance conditions for mosquitoes such as *Ae. albopictus* and this study has confirmed the potential importance of mangrove forests as a source of this important pest and vector mosquito.

3.1 Positive ovitrap index (POI) and mean larvae per trap (MLT)
The results of the 5 days interval distribution of POI and mean larvae per trap of *Ae. albopictus* in mangrove forests from June to December 2015 demonstrated temporal pattern throughout 6 month surveillance (figure 2). The mean POI varied from less than 40% (early August) to over 70% throughout late August and early September while the mean abundance of *Ae. albopictus* larvae followed a similar seasonal trend. The POI and mean larvae peaked in August and October at day 65, 70, and 75 with mean larvae per trap at 48.78, 44.93, and 49.46 respectively before a drastic drop in early November due to dry season in study area. Pearson's rank correlation test also revealed a positive association between the POI and MLT ($r=0.889$, $p<0.05$).

The results of irregular pattern of mosquito abundance throughout sampling shows there are slight similarities between previous years results by Ali *et al.* [13] that was conducted in aborigine village nearby forested area in which mosquitoes that vector malaria in mountainous region of Malaysia were subjected to rainfall and other climate factors might affected population abundance of mosquitoes.

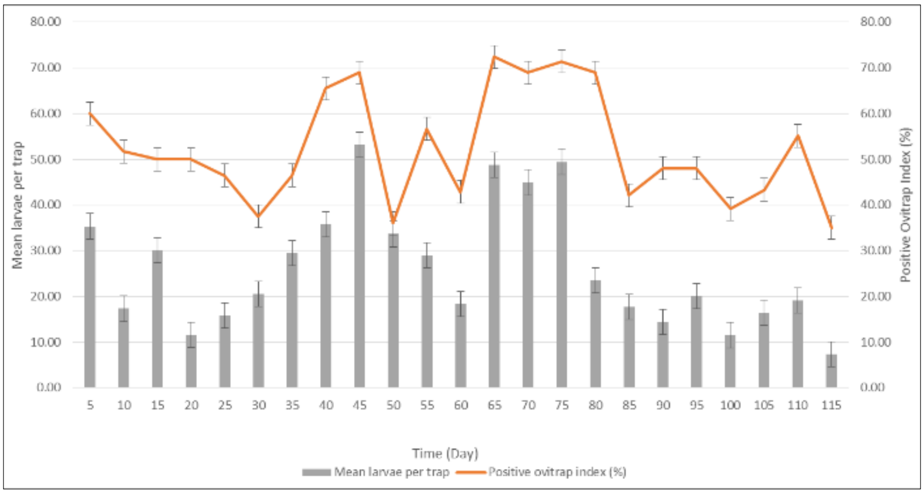


Fig 2: Temporal activity of *Aedes albopictus* based on Positive Ovitrap Index (POI) and mean number of larvae per trap (MLT) in mangrove habitats of Penang Island, Malaysia.

3.2 Spatial analysis on population abundance of *Ae. albopictus* in mangrove forest in Balik Pulau, Pulau Pinang

The spatial distribution of *Ae. albopictus* in study area were first analyzed by mean number of mosquitoes collected in each ovitrap location which were then mapped using GIS intermediate density application to visualized density distribution. The result of stratified heat map of population density (figure 3) shows scattered population density in study areas with higher density observed in areas with abundance of artificial breeding sources. Statistical analysis ANOVA for the mean number of larvae and location of ovitraps was significant $F(29,660) = 8.112$, $p<0.05$.

It is important to note that the method of sampling used in this study may potentially bias the relative measure of abundance. Ovitrap placement in study areas provides a new breeding sites for the mosquito species. Thus, the better prospect of breeding sites that provide higher rate of survival will most likely prefer by each species to ensure their population abundance [14]. Importantly, ground surveys are required to determine the relative importance of artificial compared to natural water-holding containers. Such information may be critical in assisting the development of management strategies that prioritise the reduction and clean up on plastic container rubbish in coastal wetlands associated with urban areas. Similarly, consideration should also be given to suitable mitigation strategies where mosquitoes such as *Ae. albopictus* or *Ae. aegypti* may be present in naturally occurring tree-hole habitats and may potentially be driving mosquito-borne disease risk.

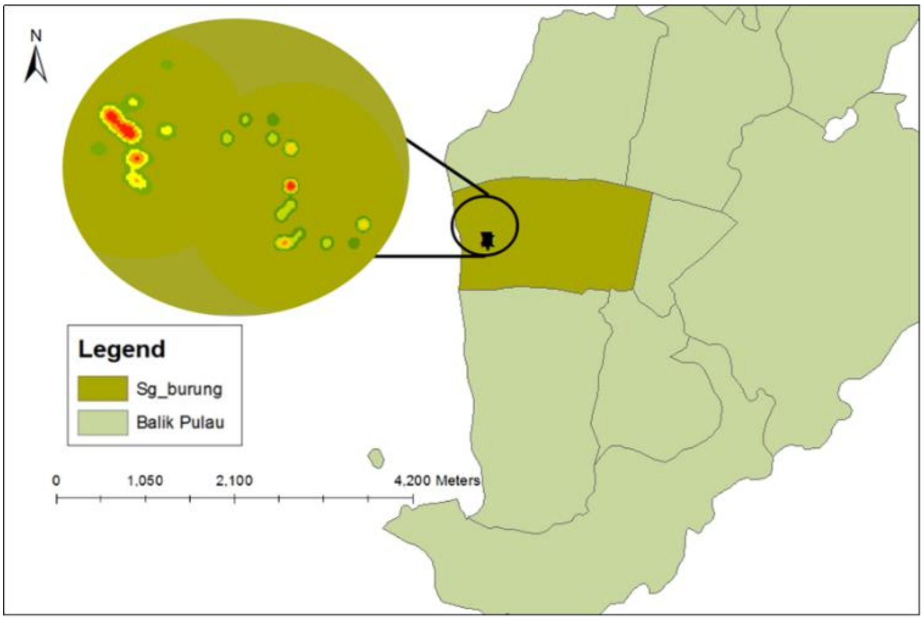


Fig 3: Spatial distribution hotspot area map on population density of *Ae. albopictus* in study area. (Source: ArcGIS 10.3 software).

3.3 Relationship between temperature, humidity and light intensity with mean larval abundance in mangrove forest in Sungai Burung, Balik Pulau

Pearson's correlation tests shows insignificant relationship between all the temperature, humidity and light intensity and larvae density of the study site. However, the spatial interpolation between parameters and mean larvae density displayed distinct patterns.

Meanwhile, spatial interpolation of meteorological parameters with population density of *Ae. albopictus* in mangrove forest of Sungai Burung, Balik Pulau was shown on figure 4. The interpolation resulted in concentrated population density at temperature range of 32.25 to 34.07°C, relative humidity 61.97 to 65.13% and light intensity at 2.49 to 2.80kLux.

It is critical to the assessment of actual and potential mosquito habitats that surrounding land use and its influences be assessed, as was the case in an Australian study by Claflin *et al.* [15] that demonstrated that container-inhabiting mosquitoes were present in urban mangrove forests and population abundance may be influenced by urban environments. This study has determined the population abundance of mangrove mosquitoes and the breeding sites preferences of respective species by using GIS application. Aside from Dengue which are pandemic to the country, malaria which was originated from mangrove ecology, and anopheline mosquitoes is potential medium of spreading the lethal disease [16]. The latent risk of Malaria outbreak is still relevant if there is no caution taken against developing these high risk areas. According to WHO [17] report in 2017, there were more than 4000 reported cases of malaria in Malaysia; almost 100% increased than 2016 with most of the cases reported were from *Plasmodium knowlesi* infection [17].

Common hosts of this zoonotic parasites are macaques and monkeys while using *Anopheline* mosquitoes as vectors to spread the infection especially to people invested in forest habitat such as farmers, logging camp workers and hunters [18]. Previous studies by Rahman *et al.* [19] and Vythilingam *et al.* [20] also confirmed that *An. hackeri* and *An. cracens* are vectors of *P. knowlesi* in which these species commonly found in forests, mangrove swamps and ponds.

Implementing the Geographical Information System (GIS) and remote sensing for spatial and temporal study of mosquitoes borne diseases, mosquito abundance and distribution has been carried out for decades [1, 21]. The results achieved from previous study by Dale and Knight [22] in Europe has encourage the Asia Pacific country to apply the same methods so as to prevent and manage the mosquitoes borne diseases. The focus of this research was to assess the hotspots of vectors mosquitoes in mangrove forests so that the health provider can treat the hotspots instead of wasting time, human resources and money to exterminate mosquito population of vastly mangrove niche.

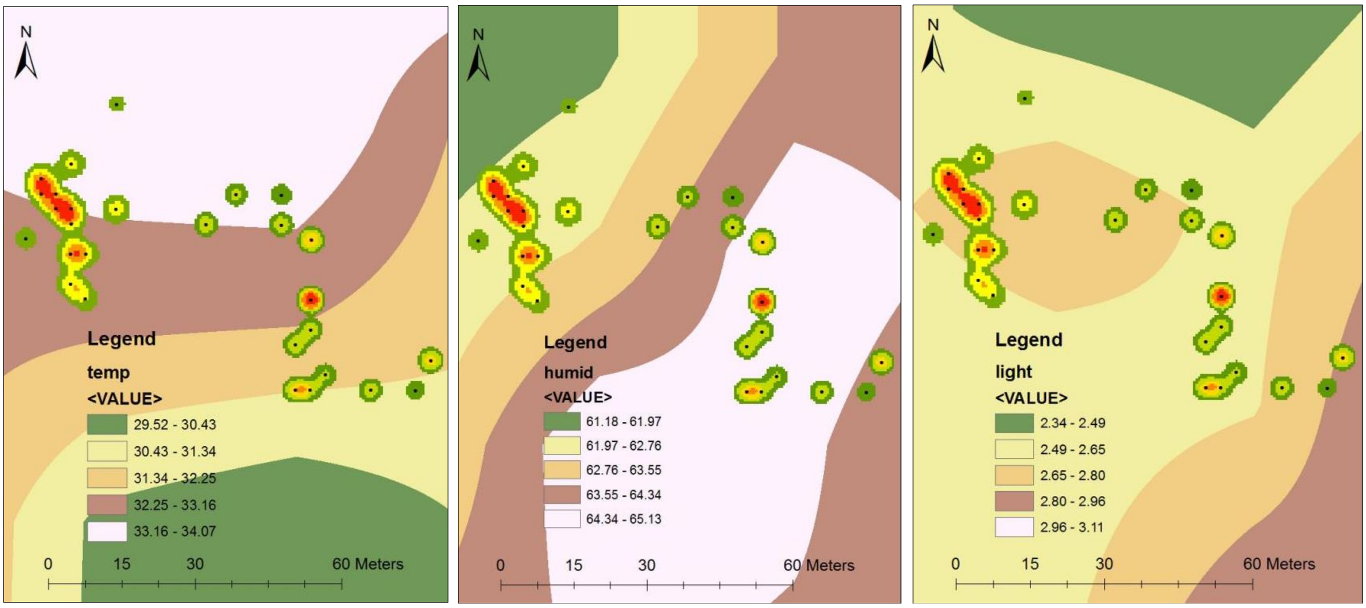


Fig 4: Spatial interpolation on population density of *Ae. albopictus* in relation to temperature, humidity and light intensity in study area. The data of meteorological parameters are interpolated to population density of *Ae. albopictus* using inverse distance weighted (IDW). (Source: ArcGIS 10.3 software).

4. Conclusion

The findings acknowledged the efficiency of ovitrap surveillance as an efficient method to study the population abundance of *Ae. albopictus*. The population density of *Ae. albopictus* mosquitoes in mangrove forests accumulated to disturbed areas than less disturbed areas suggesting the urbanization, host preferences and breeding site preferences as factors contributing to population abundance of this vector species. While meteorological parameters show insignificant relationship with population density, seasonal abundance in related to wet and dry season was depicted by a higher distribution of *Ae. albopictus* during wet season. Heat maps of population density further highlighted the distribution towards disturbed areas of mangrove areas. The distribution of *Ae. albopictus* in mangrove areas contemplate the potential outbreak of mosquito-borne disease as an aftermath of urbanization in the areas without proper risk management.

5. Acknowledgements

We thank to each of the collaborators who were involved directly or indirectly throughout this research. This study was funded by the Research University Grant Universiti Sains Malaysia (1001/PHUMANITI/811324) and External Agency Grant of Universiti Sains Malaysia, the Ministry of Natural Resources and Environment – NRE (304/PBIOLOGI/ 650880/K130). We would also like to thank the authorities of Kedah Forestry Department, Malaysia for allowing us to work on their properties.

6. References

1. Kanniah KD, Sheikhi A, Cracknell AP, Goh HC, Tan KP, Ho CS *et al.* Satellite images for monitoring mangrove cover changes in a fast growing economic region in southern Peninsular Malaysia. Remote Sensing. 2015; 7(11):14360-14385.

2. Alongi DM. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science. 2008; 76(1):1-13.
3. Tengku NSTI, Kassim NFA, Azimah AR, Khairun Y, Webb CE. Day biting habits of mosquitoes associated with mangrove forests in Kedah, Malaysia. Tropical Medicine and Infectious Disease. 2018; 3(3):77.
4. Macnae W. A general account of the fauna and flora of mangrove swamps and forests in the Indo-West Pacific region. Advances in Marine Biology. 1968; 6:73-270.
5. Giesen W, Wulffraat S, Zieren M, Scholten L. Mangrove Guidebook for Southeast Asia. Bangkok: Rap Publication, Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific, 2006, 769.
6. Ramasamy R, Surendran SN, Jude PJ, Dharshini S, Vinobaba M. Larval development of *Aedes aegypti* and *Aedes albopictus* in peri-urban brackish water and its implications for transmission of arboviral diseases. PLoS Neglected Tropical Diseases. 2011: 5(11):e1369.
7. Wan NO, Chen CD, Soh HN, Lee HL, Nazni WA, Sofian-Azirun M. Surveillance of *Aedes* mosquitoes in a university campus in Kuala Lumpur, Malaysia. Tropical Biomedicine. 2009; 26(2):206-215.
8. Jeffery J, Rohela M, Muslimin M, Abdul Aziz SMN, Jamaiah I *et al.* Illustrated Keys: Some Mosquitoes of Peninsula Malaysia. University of Malaya Press, Kuala Lumpur, 2012, 87.
9. Rattanarithikul R. A guide to the genera of mosquitoes (Diptera: Culicidae) of Thailand with illustrated keys, biological notes and preservation and mounting techniques. Mosquito Systematics, Bangkok. 1982; 14(3):139-208.
10. Serpa LLN, Marques GRAM, Lima AP, Voltolini JC, Arduino MB, Barbosa GL *et al.* Study of the distribution and abundance of the eggs of *Aedes aegypti* and *Aedes albopictus* according to the habitat and meteorological variables, municipality of São Sebastião, São Paulo State. Brazil Parasit Vectors. 2013; 6:321.
11. Tatem AJ, Hay SI, Rogers DJ. Global traffic and disease vector dispersal. Proceedings of the National Academy of Sciences of the United States of America. 2006; 103(16):6242-6247.
12. Stickel BH, Jahn A, Kier B. The Cost to West Coast Communities to Dealing with Trash, Reducing Marine Debris. United States Environmental Protection Agency, Region IX Pursuant to Order for Services EPG12900098, 2012, 2-3.
13. Ali WN, Ahmad R, Nor ZM, Ismail Z, Lim LH. Population dynamics of adult mosquitoes (Diptera: Culicidae) in malaria endemic villages of Kuala Lipis, Pahang, Malaysia. The Southeast Asian Journal of Tropical Medicine and Public Health. 2011; 42:259-267.
14. Juliano SA. Species interactions among larval mosquitoes: Context dependence across habitat gradients. Annual Review of Entomology. 2009; 54:37-56.
15. Claflin SB, Webb CE. Surrounding land use significantly influences adult mosquito abundance and species richness in urban mangroves. Wetlands Ecology and Management. 2017; 25(3):331-344.
16. Rohani A, Wan NWMA, Zurainee MN, Zamree I, Azahari AH, Mohd NI *et al.* Mapping of mosquitoes breeding sites in Pos Lenjang, Kuala Lipis, Pahang, Malaysia. Malaria Journal. 2011; 10(1):361.
17. WHO. Malaysia Malaria publication country profiles. http://www.who.int/malaria/publications/country-profiles/en/ 5 Feb, 2018.
18. Cox-Singh J, Singh B. *Knowlesi* malaria: newly emergent and of public health importance? Trends Parasitology. 2008; 24:406-410.
19. Rahman W, Che'Rus A, Hassan A. Malaria and *Anopheles* mosquitos in Malaysia. The Southeast Asian Journal of Tropical Medicine and Public Health. 1997; 28:599-605.
20. Vythilingam I, Noorazian YM, Huat TC *et al. Plasmodium knowlesi* in humans, macaques and mosquitoes in peninsular Malaysia. Parasit Vectors. 2008; 1:26.
21. Dale PE, Ritchie SA, Territo BM, Morris CD, Muhar A, Kay BH. An overview of remote sensing and GIS for surveillance of mosquito vector habitats and risk assessment. Journal of Vector Ecology. 1998; 23(1):54-61.
22. Dale PE, Knight JM. Wetlands and Mosquitoes: A review. Wetlands Ecology Management. 2008; 16:255-276.