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Research Article

Studying the Impacts of Land Use Changes on the Occurrence of Vector Mosquitoes in Sabah, Malaysia

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Abstract

Land use changes as a result of infrastructural and agricultural development such as construction of forest field centre, establishment of large-scale oil palm plantations, and logging activities are increasing in Malaysia. These activities lead to environmental disturbances and may affect the ecological balance of many organisms. Mosquitoes are very sensitive to environmental changes since their diversity, distribution and abundance are influenced by even small changes in environmental conditions such as availability of suitable breeding sites. Mosquitoes from three different sites of varying disturbance levels at the SAFE Project experimental areas in eastern Sabah i.e., old growth forest (OG), logged forest (LFE) and heavily logged forest (Block B) were collected and identified to species level. Shannon-Wiener index and Simpson index of diversity were calculated and the diversity value were highest in LFE (H'= 0.4434, 1/D= 1.3427) and the least in Block B (H'= 0.3260, 1/D= 1.1627). A similar trend was detected in terms of mosquito abundance with the highest abundance recorded in LFE and the least in Block B. Results of the present study generally suggest that land use changes do affect mosquito diversity and abundance by altering, creating or providing places for the adult mosquitoes to breed.

Keywords: Land use changes, forest disturbance, vector mosquitoes, SAFE Project, Sabah

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Introduction

The modification of habitats due to human related activities plays an important role in changing the ecological balance of many organisms, for example natural and artificial places where mosquitoes breed, develop and potentially, transmit diseases (Norris, 2004). Land use change by human activities such as logging, agriculture and urbanisation can influence mosquito diversity, distribution and abundance, as well as other aspects such as biting behaviour and vector competence (Patz et al., 2000). As an adaptation to the changed environmental conditions, such as increase in human population, some vectors have been known to convert their feeding habit from primarily zoophilic to primarily anthropophilic. Mosquitoes are more sensitive to environmental changes compared to other forest species that transmit diseases to humans, such as bats and snails because their survival, density and distribution are influenced by the small changes in the environmental conditions such as temperature, humidity and the availability of breeding sites (Yasuoka & Levins, 2007). The aim of this study was to investigate the effects of progressive land use changes in the form of logging and oil palm plantation development on the mosquito community. This paper reports the preliminary findings of the diversity, distribution and abundance of mosquitoes in several forest areas that have been subjected to different levels of disturbance due to logging activities.

Methodology

Study area

This study was conducted at the Stability of Altered Forest Ecosystem (SAFE) Project experimental areas. The SAFE Project is a forest fragmentation experiment which is aimed at understanding the impacts of forest disturbance and fragmentation, as well as conversion into oil palm plantations, on the biodiversity, ecosystem functioning and services (Ewers et al., 2011). The project area includes Kalabakan Forest Reserve and Maliau Basin Conservation Area (Figure 1).

Three different forest types were selected in this study i.e. logged forest (LFE) and heavily logged forest (Block B) in Kalabakan Forest Reserve, and old growth forest (OG) in Maliau Basin Conservation Area.

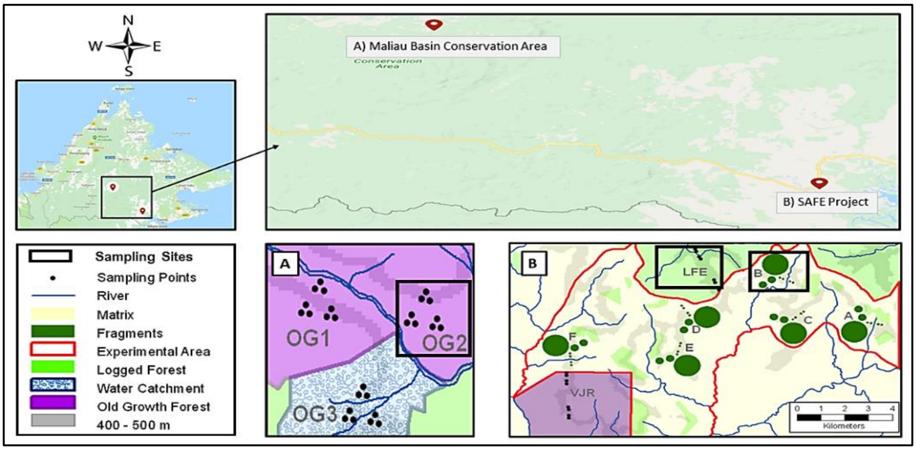

Figure 1. Map of Sabah showing the locations of study sites in Maliau Basin Conservation Area (OG2 (inset A)) and Kalabakan Forest Reserve (LFE and B (inset B)).

Adult Mosquito Sampling

Samplings of adult mosquito were conducted every alternate month from July 2017 to August 2018, for 12 nights at each study sites. A total of six survey points were selected, with two survey points (minimum separation of 500m) allocated for each sites (Table 1). Adult mosquitoes were collected by using human landing catches technique (HLC) conducted by two collectors simultaneously between 18:00 hr to 00:00 hr during every sampling occasion (Brant, 2015).

Table 1. Location of sampling points in the study sites.

Forest types	Coordinates	General habitat descriptions
Old growth forest (OG)	Survey point 1: N 04˚44' 09.8"; E 116˚58'40.1" Survey point 2: N 04˚44' 02.0"; E 116˚58'22.6"	Forest habitat which was lightly logged in 1970s and 1990s.
Logged forest (LFE)	Survey point 1: N 04°43' 24.6"; E 117°36' 11.0" Survey point 2: N 04°43' 28.8"; E 117°35'47.0"	Selectively logged in the 1970s and also from the late 1990s to the early 2000s, it has 71% forest cover.
Heavily logged forest (Block B)	Survey point 1: N 04°43' 03.4"; E 117°36' 33.5" Survey point 2: N 04°43' 39.4"; E 117°36' 51.9"	Selectively logged in the 1970s and also from the late 1990s to the early 2000s, re-logged three times, fragmented forest, it has 47% forest cover.

Source: Ewers et al. (2011); Struebig et al. (2013)

Immature Stages Sampling

Immature stages of mosquitoes were sampled at potential breeding sites such as streams, ground pools and tree holes at each study site. Collections of immature stages were conducted every month during the day between 06:00 hr to 18:00 hr and at night after 18:00 hrs. A 0.47 L standard dipper was used at the rate of 10 dips for ground pools and ditches, while 15 dips for streams and swamps (Chang et al., 1997). The samples in tree holes were collected using pipettes.

Mosquito Preservation and Identification

All collected samples of adult mosquitoes were pinned and morphologically identified to species level using compound microscope. Species identity was based on the identification key by Rattanarithikul et al., (2005a,b; 2006a,b), Reid (1968), Stojanovich & Scott (1966) and Sallum et al., (2005). The collected immature stages were preserved in 70% ethanol and identified up to genus level.

Data Analysis

Data analyses were carried using SPSS Version 20 and Microsoft Excel 2016. Shannon-Wiener's Diversity Index and Simpson's Diversity Index were used to obtain the diversity of mosquitoes collected in each site. The diversity indices were calculated by taking the number of each collected species and the proportion of the species from the total number of individuals in the samples. The variation in adult mosquito abundance between study sites was analysed using one-way ANOVA and the detailed comparisons between sampling sites was conducted using Tukey's HSD Post Hoc test. Data were first normalized to meet the normality assumptions before running the ANOVA test.

Results

Adult Mosquito Collections across Different Land Use Types

A total of 1,032 adult mosquitoes representing five different genera were collected over a cumulative total of 36 nights of sampling. They consisted of 533 anophelines and 499 culicines. Five species represented the culicines, i.e. *Aedes albopictus*, *Culex sitiens*, *Culex vishnui*, *Downsyiomia ganapathi* and *Heizmannia* sp., while the anophelines were represented by two species, i.e., *Anopheles balabacensis* and *Anopheles latens*. The results showed that *Anopheles balabacensis* was the most abundant species with 519 (or 50.29%) individuals collected and the least abundant was *Heizmannia* sp. with only one individual collected (0.19%). Out of these seven species, only those from the genus *Aedes*, *Anopheles* and *Culex* are known as vector mosquitoes and are medically important in Malaysia.

Mosquito abundance was the highest in logged forest area (LFE) with 552 individuals collected, followed by old growth forest (OG) with 302 individuals and heavily logged forest (Block B) 178 individuals (Table 2). Shannon-Wiener's index and Simpson's index were calculated and the diversity values were highest in LFE (H'= 0.4434, 1/D= 1.3427) and the least were in Block B with H'= 0.3260, 1/D= 1.1627. The variations in adult mosquito abundance between the old growth (OG), logged forest (LFE) and repeatedly logged forest (Block B) sites were significantly different (ANOVA, df= 17, F= 4.512, p= 0.029) (Figure 2).

Table 2. The abundance of mosquito species collected in different habitat types.

Genus	Species	Number of individuals (%)			No.
		OG	LFE	Block B	
Aedes	*albopictus*	7 (2.32)	474 (85.86)	3 (1.68)	484 (46.90)
Anopheles	*Balabacensis*	280 (92.72)	74 (13.41)	165 (92.69)	519 (50.29)
	latens	8 (2.65)	0 (0)	6 (3.37)	14 (1.36)
Culex	*Sitiens*	3 (0.99)	2 (0.35)	2 (1.12)	7 (0.68)
	vishnui	1 (0.33)	1 (0.19)	1 (0.56)	3 (0.29)
Downsyiomia	*ganapathi*	3 (0.99)	0 (0)	1 (0.56)	4 (0.39)
Heizmannia	sp.	0 (0)	1 (0.19)	0 (0)	1 (0.09)
Total		**302 (100)**	**552 (100)**	**178 (100)**	**1032 (100)**

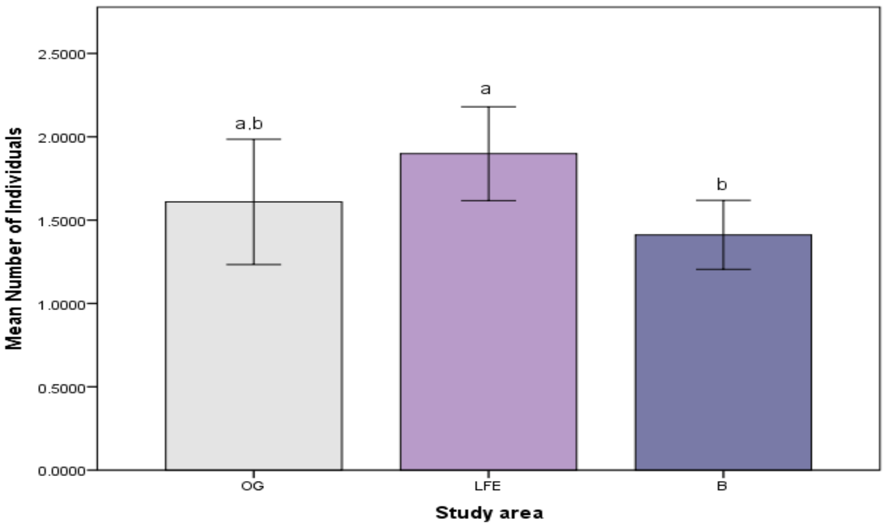

Figure 2. Adult mosquito abundance in OG, LFE and Block B. Note: Error bars indicate 95% Confidence Intervals and different letters above bars indicate significant differences derived from a Tukey-HSD post hoc test which described in the text

Post-Hoc Tests revealed that the adult mosquito abundance in LFE was significantly higher than in Block B (Tukey's HSD Post Hoc, p= 0.024), while no significant difference was detected in LFE compared to OG (Tukey's HSD Post Hoc, p= 0.212). Similarly, no significant difference was detected in OG compared to Block B (Tukey's HSD Post Hoc, p= 0.464).

Larva Collections

A total of 420 larvae from four different genera were collected from the breeding sites in this study. Five breeding sites were detected in LFE i.e., streams, ground pool, rock pool, laboratory construction site and water filled rubbish. Whereas, only two breeding sites were detected in OG and Block B i.e. streams and ground pools. Genus *Culex* recorded the highest abundance with 263 individuals collected, followed by *Aedes* with 138 individuals, *Anopheles* (10 individuals) and *Armigeres* 9 individuals. The most widespread genus was *Culex*, i.e. found in all three study sites. Genus *Aedes* was only found in OG and LFE, while *Anopheles* and *Armigeres* were found only in LFE (Table 3; Figure 3).

Table 3. Number of larvae collected from various breeding sites in the study areas.

Genus	Areas found	Breeding sites	No.	Percentage (%)
Aedes	OG, LFE	Laboratory construction site, ground pool, rock pool, empty can, water filled rubbish	138	32.86
Anopheles	LFE	Ground pool, rock pool	10	2.38
Armigeres	LFE	Laboratory construction site	9	2.14
Culex	OG, LFE, Block B	Laboratory construction site in LFE, ground pool, streams, rock pool, tree hole, empty can, water filled rubbish	263	62.62
Total			**420**	**100**

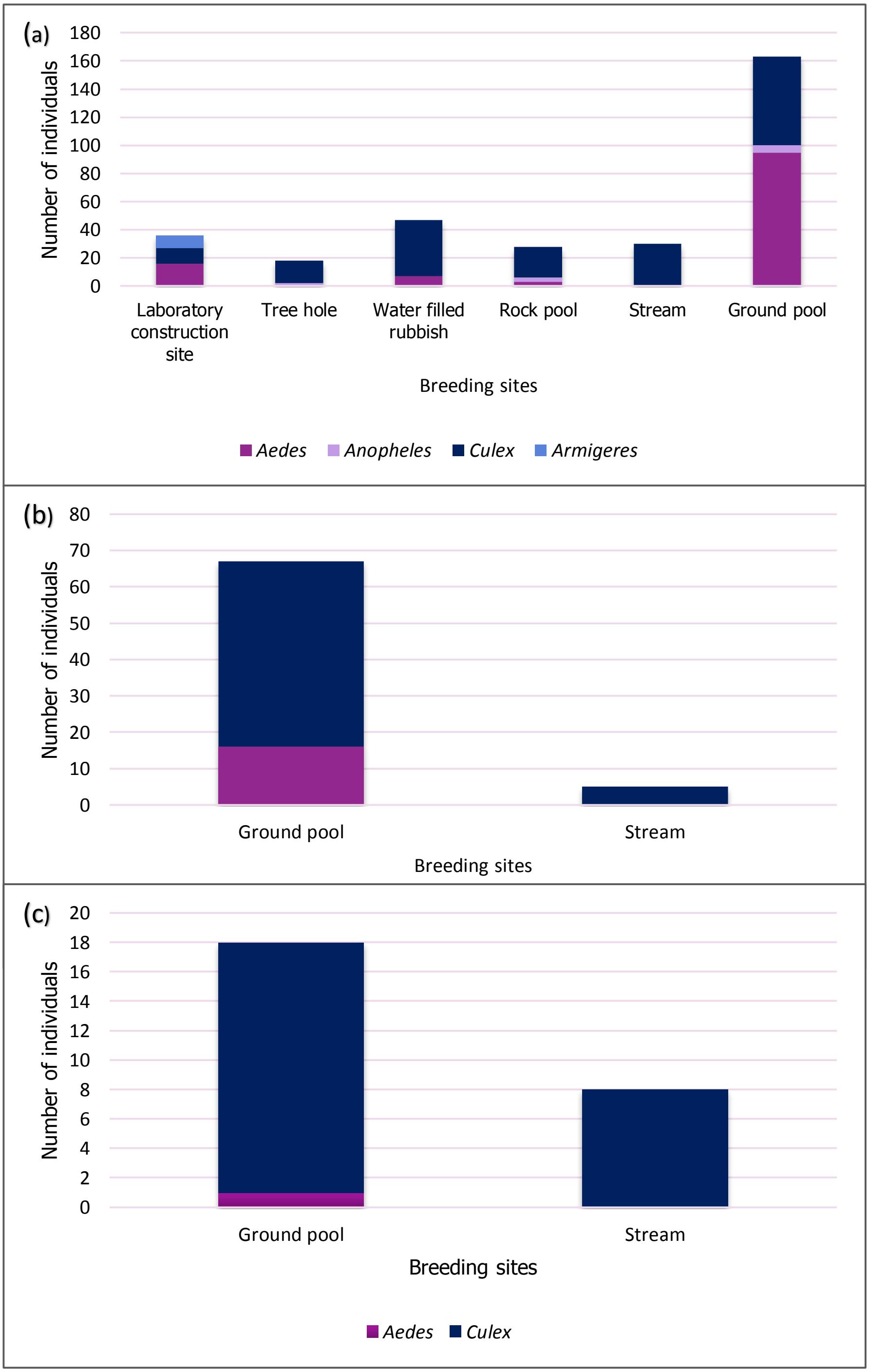

Figure 3. Number of mosquito larvae collected in (a) OG, (b) LFE and (c) Block B.

Discussion

Adult Mosquito Collections across Different Land Use Types

In this study, mosquitoes were more abundant in the logged forest area (LFE) than in old growth forest (OG). This finding is in agreement with the findings by Brant et al. (2016) and Ebrahim & Mahadimenakbar (2018). The higher abundance of mosquitoes may be attributed to the greater potential breeding sites in logged forest which were created as a result of human disturbance activities. Indeed, more breeding sites were found in LFE such as at the laboratory construction site, ground pools, tree holes, streams, empty cans and other water filled rubbish, compared to in OG and Block B, where only two breeding sites for mosquito were found i.e. ground pools and streams.

Anopheles balabacensis was found dominating two study sites; OG and Block B, while in LFE, the most frequently collected species was *Aedes albopictus*. Brant (2015) showed that *Aedes albopictus* only breeds in residential areas. LFE is a twice logged forest that is surrounded by human settlement areas and also a laboratory construction site. Since *Aedes albopictus* is anthropophilic or well known as a vector that prefers to take blood meals from humans rather than animals, this could explain why this species dominated the logged forest site (Li et al., 2014). According to Nazri et al. (2013), *Aedes albopictus* is more likely to breed in natural containers or outdoor man-made habitats containing organic debris. Based on the results of the present study, *Aedes* larvae was collected mostly from the ground pools. Wheel tracks on the ground made by 4WD vehicles used by staff and researchers residing nearby LFE sampling sites formed puddles or ground pools providing suitable breeding sites for mosquitoes, whereas in OG and Block B there were no wheel tracks present within this study area (Brant et al., 2016).

In terms of number of vector mosquito presence, all sites seemed to have the same vector species. *Aedes albopictus*, *Anopheles balabacensis*, *Anopheles latens*, *Culex sitiens* and *Culex vishnui* were found in OG and Block B. However, there was no *Anopheles latens* recorded in LFE. *Aedes albopictus* is known as a vector of dengue disease in Malaysia (Brant, 2011). The population of this species spreads widely because of its ability to live in all ecotypes in towns, villages and forest fringes (Ebrahim & Mahadimenakbar, 2018). *Anopheles balabacensis* is an exophagic and exophilic species, but could also be endophagic (Brant et al., 2016). In East Malaysia, females of this species are highly anthropophilic. Despite some of them being more anthropophilic, other subpopulation can be more zoophilic (Sallum et al., 2005). Miyagi (1973) found that this species is attracted to humans, monkeys and water buffaloes. These could be the reasons why this species was found in all study areas in the present study. In fact, they were dominant in the OG and Block B area.

Larva Collections

Habitat preference may be different among mosquito species (Haarlem & Vos, 2018). *Culex* mosquitoes could be found in natural and man-made breeding sites, but some of them are most likely to breed in stagnant polluted water (Low et al., 2012). The present study found that the most collected mosquito was from the genus *Culex* and the least was from genus *Armigeres*. The *Armigeres* larvae was collected from the laboratory construction site in LFE and was not present in OG and Block B. According to Pandian and Chandrashekaran (1980), this genus prefers to breed in foul smell and stagnant water. Clearly, more studies and greater number of sampling locations are needed to confirm the absence of this genus in the study area.

Conclusion

In general, there were differences in terms of diversity, distribution and abundance of vector mosquitoes among the different land-uses. In this study, logged forest area (LFE) showed higher mosquito abundance compared to old growth forest (OG) and heavily logged forest (Block B). The present study provided some evidence suggesting that land use changes do affect mosquito diversity and abundance and by altering, creating or providing places for the adult mosquitoes to breed. This study also found that *Anopheles balabacensis* was the dominant species collected in OG and Block B, whereas in LFE, the predominant species was *Aedes albopictus*. Since these species are important vectors for malaria and dengue, proper control methods such as removing mosquito habitat, controlling adult mosquito population by using EPA-registered pesticides and installing door or window screen need to be emphasized to the locals to prevent mosquito bites and spread of these diseases.

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