DIVERSITY AND COMPOSITION OF MOSQUITO IN STABILITY OF ALTERED FOREST ECOSYSTEM (S.A.F.E) PROJECT AREA IN KALABAKAN, SABAH

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INSTITUTE FOR TROPICAL BIOLOGY AND CONSERVATION
UNIVERSITI MALAYSIA SABAH
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DEGREE : **MASTER OF SCIENCE (ECOLOGICAL PROCESS)**

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ABSTRACT

Changing of landscapes or environment can affect mosquito diversity, abundance and composition. The objectives of this study were to investigate the diversity, abundance and composition of mosquitoes as well as their interaction to changing environment condition especially their biting time behaviour within the *Stability of Altered Forest Ecosystem* (S.A.F.E.) Project field sites, Kalabakan, Sabah and Maliau Basin Conservation Area. Mosquito collection by using manual human landing catch technique was carried out in three study sites which were logged forest area (S.A.F.E. Project field site), oil palm plantation (S.A.F.E. Project field site), and primary forest area (Maliau Basin Conservation Area). A total of 1208 adults individuals and 268 larva were collected in six months of bi-monthly sampling collection (June 2016-April 2017). There were 25 adult mosquito species from nine genera of mosquitoes were caught in this study. Adult mosquitoes collection from primary forest in this study shows a high Shannon-weiner diversity value of H'=1.90 compared to logged forest sites, H'=1.45 and oil palm sites, H'=1.27. In term of mosquito abundance, logged forest area was considered abundant compared to oil palm and primary forest due to more abundance of possible vector mosquito such as *Aedes*, *Culex* and *Anopheles* mosquito in the area. One-way ANOVA analysis shows a significant variation in adult mosquitoes abundance between study sites ($p<0.05$). However, there is no significant difference in adult mosquitoes abundance for different sampling months. Based on the spearman correlation analysis, temperature and humidity shows a significant association with adult mosquito collections ($p<0.05$) for overall day time and night time collection. For mosquito biting time, based on the day-time sampling, logged forest area had peak biting around 3.00 pm similar with primary forest area but for oil palm the biting activity usually peaked when near 6.00 pm. For night-time sampling, logged forest area and oil palm plantation have similar peak biting around 7.00-8.00 pm while for primary forest area was around 6.00 pm. The implication of the changing of forested environment from previously undisturbed environment to disturbed environment may affect the diversity, composition, abundance and behaviour of mosquitoes especially for mosquito vector which responsible for disease transmissions.

Keywords: mosquitoes diversity, abundance, temperature, humidity, day, night, biting time.

ABSTRAK

DIVERSITI DAN KOMPOSISI NYAMUK DI PROJEK S.A.F.E. KALABAKAN, SABAH

Perubahan lanskap atau persekitaran mampu memberikan kesan terhadap kepelbagaian, kelimpahan dan komposisi nyamuk. Objektif kajian ini adalah untuk mengkaji kepelbagaian, kelimpahan dan komposisi nyamuk serta interaksi mereka terhadap keadaan persekitaran yang berubah terutamanya tabiat masa gigitan di dalam kawasan lapangan Projek Stability of Altered Forest Ecosystem (S.A.F.E.), Kalabakan, Sabah dan Kawasan Pemuliharaan Maliau Basin. Pengumpulan nyamuk menggunakan kaedah secara manual dikenali sebagai kaedah tangkapan berumpankan manusia dilakukan di tiga kawasan kajian iaitu kawasan hutan yang telah dibalak (Kawasan lapangan Projek S.A.F.E), ladang kelapa sawit (Kawasan lapangan Projek S.A.F.E), dan kawasan hutan primer (Kawasan Pemuliharaan Maliau Basin). Sebanyak 1208 individu nyamuk dewasa dan 268 individu larva telah dikumpul selama enam bulan persampelan setiap selang sebulan (Jun 2016-April 2017). Terdapat 25 spesies nyamuk dewasa dari sembilan jenis genera nyamuk yang berbeza ditangkap dalam kajian ini. Hasil tangkapan nyamuk dewasa di kawasan hutan primer dalam kajian ini menunjukkan nilai diversiti Shannon-weiner yang tinggi iaitu H'=1.90 berbanding kawasan yang telah dibalak, H'=1.45 dan kawasan kelapa sawit, H'=1.27. Dari segi kelimpahan nyamuk, kawasan hutan yang telah dibalak dikira sebagai kawasan lebih banyak nyamuk berbanding kawasan kelapa sawit dan hutan primer disebabkan oleh kelimpahan nyamuk vektor seperti Aedes, Culex dan Anopheles di kawasan tersebut. Hasil analisis One-way ANOVA menunjukkan terdapat perbezaan yang signifikan terhadap kelimpahan bilangan nyamuk dewasa diantara kawasan kajian ($p<0.05$). Walaubagaimanapun, tiada perbezaan yang signifikan terhadap kelimpahan bilangan nyamuk dewasa di antara bulan persampelan. Berdasarkan analisis korelasi spearman, suhu dan kelembapan menunjukkan perkaitan yang signifikan terhadap tangkapan nyamuk dewasa ($p<0.05$). Bagi masa gigitan nyamuk, berdasarkan persampelan waktu siang, kawasan hutan yang telah dibalak adalah sekitar jam 3.00 petang sama seperti kawasan hutan primer tetapi masa gigitan bagi kawasan kelapa sawit selalunya meningkat apabila hampir jam 6.00 petang. Bagi persampelan waktu malam, kawasan hutan yang telah dibalak dan ladang kelapa sawit mempunyai masa gigitan yang sama iaitu sekitar jam 7.00-8.00 malam manakala kawasan hutan primer adalah sekitar jam 6.00 petang. Implikasi perubahan persekitaran berhutan yang asalnya adalah persekitaran tidak terganggu kepada persekitaran terganggu mampu memberikan kesan terhadap kepelbagaian, komposisi, kelimpahan dan perilaku nyamuk terutamanya terhadap nyamuk vektor yang bertanggungjawab menyebarkan penyakit.

***Kata kunci**: Kepelbagaian nyamuk, kelimpahan, suhu, kelembapan, siang, malam, masa gigitan.*

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
GLMM	Generalized Linear Mixed Model
HLC	Human Landing Catch
LF	Logged Forest
MBCA	Maliau Basin Conservation Area
OP	Oil Palm Plantation
PF	Primary Forest
S.A.F.E.	Stability of Altered Forest Ecosystem
VJR	Virgin Jungle Reserve
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Forest Modification and Mosquito

Tropical rainforest area is known for its importance for providing suitable habitats for animals and plants. Due to its importance and uniqueness to the ecosystems, rapid forest loss and degradation at alarming rate receive the greatest attention worldwide (Laurance, 2010). Altered forest environment caused by habitat destruction usually not able to support the native species as the species become intolerant to the disturbance (Laurance, 2010; Schowalter, 2012). Several other factors such as land-use change, disease, and invasive species also act as species loss contributor (Sodhi *et al.*, 2009).

The dynamic of urbanization and population growth in South-East Asia led to the intensification of food production, agricultural, livestock, and land-use which has resulted in deforestation and inevitably climate change (Lian Lim *et al.*, 2014). For instance, some of Borneo's forested areas are being rapidly logged for the foundation or expansion of oil palm plantation or rubber plantation (Laurance, 2007; Koh *et al.*, 2008). Oil palm is considered as one of the major economic contributor to Malaysia and Indonesia (Sayer *et al.*, 2012). Forest modification will inevitably caused the ecological disturbance in the forest ecosystem and become a great threat to forest biodiversity (Fitzherbert *et al.*, 2008). Studies by Savilaakso *et al.* (2014) and Fayle *et al.* (2010) showed that after the conversion of forest area into oil palm plantation, species richness was reduced significantly compared to primary and secondary forest area and the species composition assemblages was also affected significantly.

Mosquito diversity may be changed across landscape including changes in habitat which can affect species relative abundance and the invasion of new species (Thongsripong *et al.*, 2013). Forest disturbance can be the contributing factor that led the increase of vector-borne disease transmission rate in humans and animals (Vanwambeke *et al.*, 2007; Vittor *et al.*, 2006). This can be explained when the ecological balance is disturbed, the new niches that emerge will encourage infectious agents like a parasite to adapt and change (Lian Lim *et al.*, 2014). Disturbance effect such as deforestation and road development can lead to an increasing mosquito abundance as well as biting frequency (Afrane *et al.*, 2011). Also, flooding and canopy opening affected by deforestation is believed to increase the habitat for vector insects especially mosquito (Scholwalter, 2012). Natural phenomenon or human intervention that change the environmental condition can alter the ecological balance between vectors and parasites in term of their breeding, development, and transmission (Patz *et al.*, 2000).

Mosquitoes are responsible for the transmissions of many infectious diseases (Service, 2008; Rasool *et al.*, 2015). Some of these mosquito-borne diseases are still major the problems in the tropic (Vythilingam *et al.*, 1992). The emergence of vector-borne disease is usually associated with environmental factors such as climate and habitat where changes in climate can affect the transmission of vector-borne disease (Patz *et al.*, 2008). In addition, the length of rainy and dry seasons can also affect on abundance and development of adult and larvae mosquito vector. Forest modification not only affect changes in landscape but it also affect local weather significantly. The transition of forest land from its previous primary forest state can result in environmental stress due to microclimatic changes (Edwards *et al.*, 2014). Environment plays a major role in affecting the mosquito diversity and abundances, where, favorable environment tends to increase the diversity and abundance of mosquito due to increasing availability of breeding sites. A study by Kweka *et al.*, (2016) showed that deforestation affects microclimate condition and mosquito survivorship where an increase in malaria vector reproductive rate was associated with an increase in temperature. Temperatures and humidity are among the influential microclimatic factors that affect vector-borne disease transmission mechanism. Temperature can affect growth of vector mosquito by altering their biting rates and population dynamics (Patz *et al.*, 2003). Vector insect activity like mosquito was influenced by humidity factor, where, survival decrease under dry conditions which makes them easily dessicate (Patz *et al.*, 2003). Landscape change influence on microclimate condition of an area which can be the key to determining the effect on diversity, abundance and survivorship of the mosquitoes (Patz *et al.*, 2006). Changes in mosquito diversity can affect the risk of infectious diseases in a system by disrupting their normal host and pathogen relationships (Thongsripong *et al.*, 2013). According to Thongsripong *et al.* (2013) understanding vector community which lives in an area that undergone anthropogenic changes can form the basis for understanding the emergence and persistence of mosquito-borne diseases.

1.2 Justification

The goals of this study were to investigate the variation of mosquito diversity, composition, abundance as well as its ecological interaction with tem in different types of landscapes. A previous study by Brant (2011) in Stability of Altered Forest Ecosystem (S.A.F.E.) showed that there was a significant impact of forest modification on mosquito population and suggesting that longer term study can be carried out to compare differences in the mosquito populations in different seasons. A study by Psomas (2015), highlighted that effect of microclimate changes due to forest alteration in Sabah significantly affecting the rate of immature stages of mosquito development and impacting the disease transmission by vector mosquitoes. Although there were several mosquito studies had been conducted in the SAFE Project site before such as Brant (2011) and Brant *et al.*, (2016) hopefully this study was able to complement the existing data as well as providing new information on mosquito at Kalabakan Forest Reserve area. Mosquito surveillance can help to improve good vector control as knowing the bionomic of vector mosquito can be important in order to understand how does the environment affect the transmission and how it becomes an effective vector of diseases.

1.3 Project Aims and Objectives

The purpose of this ecological study of mosquito is to study the interactions of mosquitoes with their environments such as habitat type, temperature, and humidity and to see how these parameters affecting diversity, composition, abundance and behaviour of mosquitoes in the three different sites (Primary forest, Oil palm plantation and logged forest site) since there are very few available information on the abundance and behaviour of the vector mosquitoes in newly opened areas. The main objectives of this study were:

i. To determine the diversity, composition, and abundance of anthrophilic mosquitoes in primary forest, logged forest and oil palm landscape.
ii. To study the effects of temperature and humidity on the mosquito collection in primary forest, logged forest and oil palm landscape.
iii. To study the biting behaviour and body size of mosquito in primary forest, logged forest and oil palm landscape.

1.4 Research Hypothesis

The research hypothesis in this study are:

H_0: There is no difference in mosquito diversity, composition, and abundance in each study area.

H_1: There is a significant difference in mosquito diversity, composition, and abundance in each study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

2.1.1 Mosquito

Mosquitoes are slender, a two-winged insect with an elongated proboscis (Harbach *et al.*, 2014). It belongs to order Diptera, suborder Nematocera, and family Culicidae. Insects in this suborder possess a primitive characteristic (Mohamad Fadzil, 1991; Williams *et al.*, 1992). It was categorized as order Diptera as it has a pair of a functional wing for flight. There are about 41 genera and more than 3500 mosquito species that can be found in the world (Service, 2008; Rueda, 2008; Harbach *et al.*, 2014). Even though there about 3500 about named mosquito species only a number of this very diverse family are considered medically important and bring a nuisance to human (Fang, 2010). Culicidae is the largest family group and abundantly found in the temperate and tropic region and absent in Antartica and some island (Service, 2008). There are three main subfamilies in Family Culicidae which are Anophelinae, Culicinae dan Toxorhynchitinae (Service, 2008). In Malaysia, particularly there are about four important mosquito genera that are considered to be common disease vector which is *Aedes*, *Anopheles*, *Culex*, and *Mansonia* (Rahman *et al.*, 1997).

2.1.2 Diversity of Mosquito species in South-East Asia, Malaysia, and Sabah

Mosquito diversity varies among different geographical regions of the world. The Oriental region is also known as South-East Asia region have about 30% of the mosquito diversity where mosquito from tribe *Aedini* have the most number of species followed by Culicine and the least number of species comes from Tribe Aedeomyiini (Rueda, 2008). Malaysia is one of the tropical countries that have the largest number of total mosquito species and endemic species (Foley *et al*., 2007). Previous mosquito study by Rahman *et al*. (1997) found that there are 434 species of mosquito representing from 20 different genera in Malaysia.

In Sabah, there are several studies have been conducted to assess mosquito diversity and composition. Based on the previous study by Rohani *et al*. (2008) in Ranau, Sabah, they found about 41 species of mosquito representing from eight genera (*Aedes, Anopheles, Armigeres, Culex, Coquillettida, Lutzia, Mansonia,* and *Uranotaenia*). A study by Brant *et al*. (2016) in Kalabakan Forest Reserve, Sabah found about 21 species of mosquito from ground level while 10 species found from canopy level. A seasonality study of *Anopheles* mosquito by Wong *et al.* (2015) found that there are about 10 species of *Anopheles* mosquito were found in a study at Kudat Division where in the study *Anopheles balabacensis* were the predominant species while the other Anopheles species such as *Anopheles donaldi*, *Anopheles maculatus*, *Anopheles tessellatus* and *Anopheles umbrosus* found in a very low number. Table 2.1 shows list of some of medically important mosquito in Malaysia while Table 2.2 shows the list of mosquito species found in Sabah.

Table 2.1: Some of the medically important mosquito species found in Malaysia

Species	Disease transmitted
Aedes aegypti	Dengue, Chikungunya virus
Aedes albopictus	Dengue, Chikungunya virus
Anopheles balabacensis	Malaria
Anopheles donaldi	Malaria
Anopheles maculatus	Malaria
Anopheles campestris	Malaria, Malayan filariasis
Anopheles peditaeniatus	Bancroftian & Malayan filariasis
Culex gelidus	Bancroftian & Malayan filariasis, Chikungunya virus
Culex quinquefasciatus	Bancroftian & Malayan filariasis
Mansonia uniformis	Bancroftian & Malayan filariasis, Chikungunya virus

Source: Rattanarithikul *et al*., 2005a, Rattanarithikul *et al*., 2005b; Rattanarithikul *et al*., 2006a, Rattanarithikul *et al*., 2006b; Service, 2008; Mohd Pozi *et al*., 2015

Table 2.2: List of mosquito species found in Sabah

Species recorded in Sabah	References
Anopheles *An. aitkenii* group , *An. barbirostris* *An. balabacensis, An. latens* *An. macarthuri, An. maculatus* *An. watsonii, An. donaldi* *An. umbrosus* group, *An. tessellatus* *An. flavirostris, An. aconitus, An. argyropus* *An. introlatus An. karwari, An. kochi* *An. peditaeniatus, An. philippinensis,* *An. vagus, An. vanus*	Rohani *et al*., 2008; Wong *et al*., 2015; Brant *et al*., 2016
Aedes *Ae. albopictus, Ae. alboscultellatus* *Ae. flavipennis, Ae. lineatopennis* *Ae. poicilius, Ae. vexans, Pr. ostentatio*	Rohani *et al*., 2008; Brant *et al*., 2016
Armigeres *Ar. confusus, Ar. jugraensis, Ar. balteatus Ar. flavus, Ar. malayi, Ar. pendulus*	Rohani *et al*., 2008; Brant *et al*., 2016
Culex *Cx. bitaeniorhynchus, Cx. fragilis, Cx. sitiens, Cx. gelidus, Cx. fuscocephala,* *Cx. nigropunctatus, Cx. pseudovishnui,* *Cx. quinquefasciatus, Cx. tritaeniorhynchus,* *Cx. vishnui, Cx. (lophoceraomyia), Lutzia* sp.	Rohani *et al*., 2008; Brant *et al*., 2016
Coquillettedia *Cq. pseudotaeniatus, Cq. crassipes*	Rohani *et al*., 2008; Brant *et al*., 2016
Downsiomyia *Do. ganapathi*	Rohani *et al*., 2008; Brant *et al*., 2016
Mansonia *Ma. annulifera, Ma. dives, Ma. indiana,* *Ma. uniformis*	Rohani *et al*., 2008
Uranotaenia *Uranotaenia* sp.	Rohani *et al*., 2008

Source: Rohani *et al*., 2008; Wong *et al*., 2015; Brant *et al*., 2016

2.2 Mosquito And The Effect of Environmental Condition

2.2.1 Land-Use effect

Habitat disturbances caused by land-use change strike a serious concern over the altered risk of infectious diseases. The effect of changing forest ecosystem has brought human in contact with new species of organism and disrupted existing ecosystem which allows the emergence of disease due to population shift occurred (Beltz, 2011). Factor that trigger land-use change is mostly due to economic and development reasons (Lian Lim *et al*., 2014). Nevertheless, changing habitat can influence biodiversity, abundance, and survivability of mosquito where it may affect breeding sites of the vector and the biodiversity of vector and reservoir host. For instance, agricultural development worldwide has resulted in the increased crop irrigation requirement where it reduces water availability for other uses and providing breeding sites for disease vector (Patz *et al*., 2008). The effect of land-use on mosquito abundance and disease transmission is important however because of only a few diseases have been understood it makes this issues becoming more complex to understand.

2.2.2 Microclimate Effect on Mosquito

Natural disaster and climate play an important role in disease emergence (Beltz, 2011). Environment factors such as temperature, rainfall and humidity can influence mosquito abundance (Patz *et al*., 2008). Changes in optimal climatic condition can greatly alter disease transmission by mosquito (Patz *et al*., 2003). The climate of the tropical and subtropical area seems to favor parasitic disease transmissions by arthropods (Bogitsh *et al*., 2013). Also, increasing global temperature seems to have aided in mosquito survivability and distribution (Boslaugh, 2008; Reinhold *et al*., 2018). In addition, the effect of land modification caused changes in temperature and moisture which resulted in increasing vector population and transmission rates (Geist, 2006). Temperature may affect mosquito adaptation to temperature changes by changing geographical distribution (Patz *et al*., 2003). Humidity also influence mosquito-borne disease transmission. Where the effect of low relative humidity may lead to dehydration which affect mosquito survival (Umaru *et al*., 2016).