MOSQUITOES OF THE MARAI PARAI - GURKHA HUT, KOTA BELUD AREA, RANAU, SABAH, MALAYSIA

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ABSTRACT

A mosquito study was conducted during the Marai Parai-Gurkha Hut Scientific Expedition at the Kota Belud area, Ranau, Sabah from 7th to 20th October 2023. The study aimed to record mosquito species along the trail from Marai Parai station to Gurkha Hut station, focusing especially species that have the potential to spread diseases to humans. Sampling sessions were conducted at three sampling sites: Kg Kiau Nuluh Basecamp, Nunuk Subcamp, and Marai Parai Subcamp. Mosquitoes were collected using standard approaches, including the Human Landing Catch (HLC) and Daytime Resting Collection techniques. A total of four genera of mosquitoes were recorded from Kg Kiau Nuluh Basecamp and Nunuk Subcamp, with *Aedes albopictus* (16.67%, n = 7) and *Armigeres subalbatus* (16.67%, n = 7) being the most common species, followed by *Aedes* sp. (9.52%, n = 4), *Anopheles aitkenii* (9.52%, n = 4), *Armigeres moultoni* (9.52%, n = 4), and *Armigeres giveni* (9.52%, n = 4). Additionally, female mosquitoes were found to be predominant across all species. The findings from this study can serve as baseline data for further ecological studies and monitoring of vector control in the area.

Keywords: *Aedes, Anopheles, Armigeres,* mosquito, Sabah

INTRODUCTION

Mosquitoes play a substantial role in the ecosystem, serving as prey for various organisms, contributing to pollination, and acting as vectors of disease (Rueda, 1970). Their significance extends beyond being mere components of the food chain, as they have a profound impact on human and animal health (Hall & Tamïr, 2021). Mosquito-borne diseases such as malaria, dengue fever, Zika virus, and West Nile virus pose significant global public health challenges (Smith et al., 2014). The transmission of these diseases occurs through the bite of infected mosquitoes, making mosquitoes key players in the spread of these pathogens (Becker et. al., 2003). Despite their ecological importance, the potential health risks associated with mosquito-borne diseases highlight the need for effective vector control measures to mitigate their impact on human populations (Kittichai et al., 2023). Understanding the diverse array of mosquito-borne diseases underscores the importance of knowing the species composition, as it provides insights into their varying transmission dynamics and potential threats to human populations.

During the Marai Parai-Gurkha Hut Scientific Expedition from 7th to 20th October 2023, a study on mosquito diversity was conducted at three sampling sites: Kg Kiau Nuluh Basecamp, Nunuk Subcamp and Marai Parai Subcamp. This research focuses on biting mosquitoes, which have the potential to spread diseases to humans.

METHODOLOGY

a) Study Area

The study was conducted at three sampling sites along the Marai Parai to Gurkha Hut trail (Figure 1). These sites are Kampung Kiau Nuluh Basecamp, Nunuk Subcamp and Marai-Parai Subcamp, which is about 5.2 kilometres apart. Kg Kiau Nuluh Basecamp and Nunuk Subcamp are about 2.66 kilometres apart, meanwhile, Nunuk Subcamp and Marai Parai Subcamp are about 2.54 kilometres apart. Kg Kiau Nuluh Basecamp is approximately at latitude 116.490°E, and longitude 6.040°N at 880 m above sea level. Nunuk Subcamp is approximately at latitude 116.500°E, and longitude 6.040°N at 1,215 m above sea level. Marai Parai Subcamp is approximately at latitude 116.520°E, and longitude 6.080°N at 1,652 m above sea level.

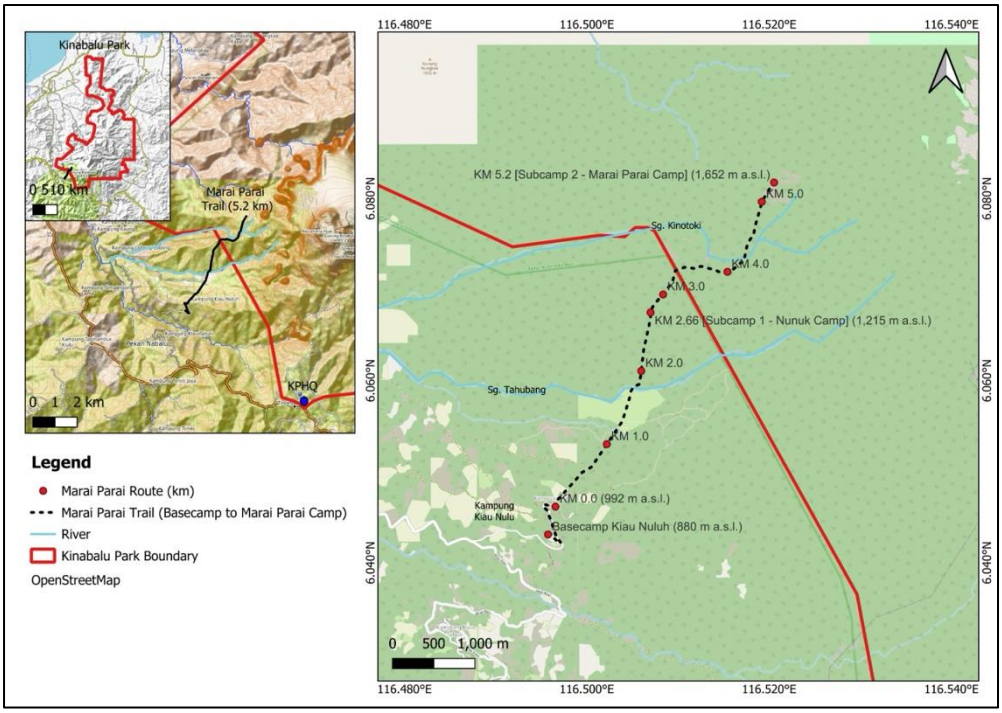

Figure 1. Map of the Marai Parai-Gurhka Hut routes

b) Mosquito Sampling and Collection

In this study, two approaches were incorporated to sample the mosquitoes: Human Landing Catch technique (HLC) and the Daytime Resting Collection. These collection techniques were selected because the methods are important in gathering baseline ecological and entomological data before implementing mosquito control programs (Shengxin et al., 2022).

The Human Landing Catch technique involves using human as bait to attract mosquitoes for biting. This method involves individuals sitting still for a set period while mosquitoes land and attempt to bite (Ebsworth, 2004). Once the mosquitoes have landed and attempted to bite, they are collected and placed in a jar for later identification.

Meanwhile, Daytime Resting Collection involves searching for mosquitoes in dark, cool, and humid places where they may rest during the day (Hurd et al., 2002; Ebsworth, 2004). This technique is useful for mosquitoes that do not rely on host-seeking behaviour. Once the mosquitoes are collected, they will be put inside the collection jar.

c) Species Identification

The mosquitoes were identified in the laboratory based on morphological characterisation using interactive identification keys, dichotomous keys, reference literature, and illustrated identification keys (Jourdain et al., 2018), where illustrated identification keys were the commonly used, followed by dichotomous keys, reference literature, and lastly interactive identification keys. Morphological characterisation of the mosquitoes was observed using image analyser and digital microscope.

d) Data Analysis

To assess the composition of the mosquito's community in each site, three indices were computed: Shannon's Diversity Index (H') quantifying the mosquitoes' diversity and Pielou's Evenness Index (J') calculating whether species are distributed evenly.

RESULTS

Four genera of mosquitoes, *Aedes*, *Anopheles*, *Armigeres*, and *Culex* were identified among a total of 42 individuals of adult mosquitoes (Table 1). *Aedes albopictus* (16.67%, n = 7) and *Armigeres subalbatus* (16.67%, n = 7) were the most frequently recovered mosquito species followed by *Aedes sp.* (9.52%, n = 4), *Anopheles aitkenii* (9.52%, n = 4), *Armigeres moultoni* (9.52%, n = 4), and *Armigeres giveni* (9.52%, n = 4).

Aedes, *Armigeres* and *Culex* were found at Kg Kiau Nuluh Basecamp and Nunuk Basecamp. For *Anopheles*, it was only found at Nunuk Subcamp. There were no mosquitoes found at Marai Parai Subcamp.

Armigeres was the most abundant genus found in the study area, with a total of 17 individuals, followed by *Aedes*, with a total of 13 individuals, and *Anopheles* and *Culex*, with a total of six individuals each.

Table 1. Data of Mosquitoes Genus at Three Campsites

Sampling Location	Genus Of Mosquitoes				Total
	Aedes	*Anopheles*	*Armigeres*	*Culex*	
Kg Kiau Nuluh Basecamp	8	-	12	1	21
Nunuk Basecamp	5	6	5	5	21
Marai Parai Basecamp	-	-	-	-	-
Total	13	6	17	6	**42**

Table 2. Shannon's Diversity Index of Mosquitoes Genus in Each Campsite

Genus	Campsite								
	Kg Kiau Nuluh Basecamp			Nunuk Subcamp			Marai Parai Subcamp		
	ni/N	Log (ni/N)	(ni/N)*(log ni/N)	ni/N	Log (ni/N)	(ni/N)*(log ni/N)	ni/N	Log (ni/N)	(ni/N)*(log ni/N)
Aedes	0.1904762	-0.7201593	-0.137173201	0.119048	-0.924279286	-0.11003325	0	0	0
Anopheles	0	0	0	0.142857	-0.84509804	-0.12072829	0	0	0
Armigeres	0.2857143	-0.544068	-0.155448013	0.119048	-0.924279286	-0.11003325	0	0	0
Culex	0.0238095	1.232493	0.038648793	0.119048	-0.924279286	-0.11003325	0	0	0
H'			**0.253972421**			**0.450828036**			**0**

Table 2 shows the Shannon's Diversity Index of mosquito genera in each campsite: Kg Kiau Nuluh, Nunuk Subcamp, and Marai Parai Subcamp. The Shannon's Diversity Index of mosquito genera at Nunuk (0.45) was higher than Kiau Nuluh Basecamp (0.25)

Table 3. Species of Mosquitoes at Three Campsites

Mosquitoes Species	Campsites			Total
	Kg Kiau Nuluh Basecamp	Nunuk Subcamp	Marai Parai Subcamp	
Aedes aegypti	1	1	-	2
Aedes albopictus	7	-	-	7
Aedes sp.	-	4	-	4
Anopheles aitkenii	-	4	-	4
Anopheles spp.	-	2	-	2
Armigeres giveni	2	2	-	4
Armigeres moultoni	3	1	-	4
Armigeres spp.	-	2	-	2
Armigeres subalbatus.	7	-	-	7
Culex pseudosinensis	-	3	-	3
Culex quinquefaciatus	-	1	-	1
Culex spp.	1	1	-	2
Total	21	21	0	**42**

Table 3 shows the data species of the mosquitoes from three sampling sites. There were two *Aedes* species that have been successfully identified (*Aedes aegypti* and *Aedes albopictus*), one *Anopheles* species (*Anopheles aitkenii*), three *Armigeres* species (*Armigeres giveni, Armigeres moultoni, Armigeres subalbatus*), and two *Culex* species (*Culex pseudosinensis, Culex quinquefaciatus*) from the campsite areas. For unknown species, there were four individuals from genus *Aedes*, two individuals from the genera *Anopheles*, *Armigeres*, and *Culex* respectively.

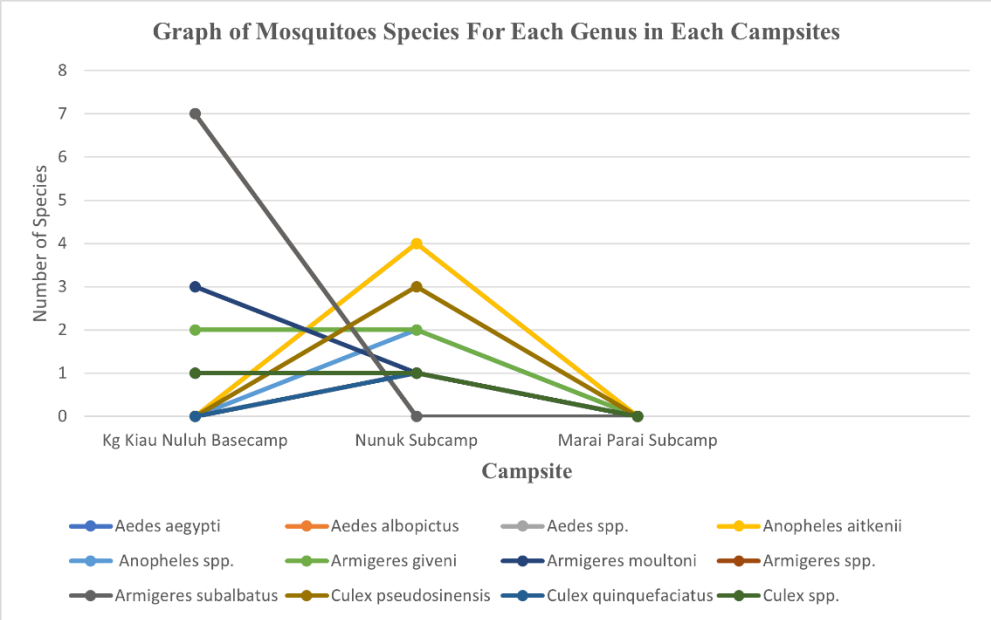

Figure 3. Graph of Mosquito Species for Each Genus in Each Campsite

Table 4. Table of the Mosquito species Percentage and Sex Ratio

Mosquitoes species	Individual collected (♀, ♂)	Percentage of total (%)	Sex ratio (♀, ♂)
Aedes aegypti	2 (1♀, 1♂)	4.76	1 : 1
Aedes albopictus	7 (4♀, 3♂)	16.67	1 : 0.8
Aedes sp.	4 (4♀, 0♂)	9.52	1 : 0
Anopheles aitkenii	4 (4♀, 0♂)	9.52	1 : 0
Anopheles spp.	2 (1♀, 1♂)	4.76	1 : 1
Armigeres giveni	4 (4♀, 0♂)	9.52	1 : 0
Armigeres moultoni	4 (4♀, 0♂)	9.52	1 : 0
Armigeres spp.	2 (2♀, 0♂)	4.76	1 : 0
Armigeres subalbatus	7 (7♀, 0♂)	16.67	1 : 0
Culex pseudosinensis	3 (3♀, 0♂)	7.14	1 : 0
Culex quinquefaciatus	1 (1♀, 0♂)	2.38	1 : 0
Culex spp.	2 (2♀, 0♂)	4.76	1 : 0
Total	42 (37♀, 5♂)	100.0	1 : 0.2

Table 4 shows the data percentage of mosquito species and sex ratio: *Aedes aegypti* (4.76%, n = 2, female = 1, male = 1), *Aedes albopictus* (16.67%, n = 7, female = 4, male = 3), *Aedes sp.* (9.52%, n = 4, female = 4, male = 0), *Anopheles aitkenii* (9.52%, n = 4, female = 4, male = 0), *Anopheles spp.*

(4.76%, n= 2, female = 1, male = 1), *Armigeres giveni* (9.52%, n = 4, female = 4, male = 0), *Armigeres moultoni* (9.52%, n = 4, female = 4, male = 0), *Armigeres spp.* (4.76%, n = 2, female = 2, male = 0), *Armigeres subalbatus* (16.67%, n = 7, female = 7, male = 0), *Culex pseudosinensis* (7.14%, n = 3, female = 3, male = 0), *Culex quinquefaciatus* (2.38%, n = 1, female = 1, male = 0), and *Culex spp.* (4.76%, n = 2, female = 2, male = 0).

DISCUSSION

The mosquitoes were only recorded from Kg Kiau Nuluh Basecamp and Nunuk Subcamp. There was no mosquito found at Marai Parai Subcamp. Some common genera found at Kg Kiau Nuluh Basecamp were *Aedes*, *Armigeres*, and *Culex*. As for Nunuk Subcamp, the genera of mosquitoes found were *Aedes*, *Anopheles*, *Armigeres*, and *Culex* (Table 1). From the collected samples, *Aedes albopictus* (16.67%, n = 7) and *Armigeres subalbatus* (16.67%, n = 7) were the most common species. Following that are *Aedes* sp. (9.52%, n = 4), *Anopheles aitkenii* (9.52%, n = 4), *Armigeres moultoni* (9.52%, n = 4), and *Armigeres giveni* (9.52%, n = 4). *Culex quinquefaciatus* was the least species of the mosquitoes collected (2.38%, n = 1). Also found that female was the predominant mosquitoes (37 individuals) compared to male (5 individuals). The mosquito fauna in the study site was notably diverse; however, *Aedes* mosquitoes were the most dominant in terms of relative abundance. Their prevalence and abundance may be attributed to their sylvatic origins in the tropical forests of Southeast Asia (Rakotonirina et al., 2023).

Nunuk Subcamp has the highest genus diversity of mosquitoes compared to Kg Kiau Nuluh Basecamp. *Aedes* and *Armigeres* were the predominant genera of mosquitoes at Kg Kiau Nuluh Basecamp, on the other hand, the predominant mosquito genera at Nunuk Subcamp were *Aedes* and *Anopheles*. The data (Table 1) indicated that *Anopheles* mosquitoes were exclusively found in the forest area, specifically at the Nunuk Subcamp, while the other genera of mosquitoes can be found in both campsites, Kg Kiau Nuluh Basecamp and Nunuk Subcamp.

As for the species diversity, *Aedes albopictus* and *Culex pseudosinensis* were the predominant species based on the whole campsites data (Table 3). Meanwhile, *Culex spp.* was the least species found in all the campsites area (Table 3). The species diversity of mosquitoes also analyzed for each of the campsites. For Kg Kiau Nuluh Basecamp, the predominant species were *Aedes albopictus* and *Armigeres subalbatus* (Table 3). Meanwhile, the predominant species of mosquitoes at Nunuk Subcamp were *Aedes* spp. and *Anopheles*

aitkenii (Table 3). The diversity of mosquito faunas in Marai-Parai likely being influenced by the elevations, where each base camp located at different elevation with Kampung Kiau Nuluh Basecamp, is approximately at 880 m above sea level, Nunuk Subcamp is at 1,215 m above sea level and Marai Parai Subcamp is at 1,652 m above sea level. The abiotic and biotic factors including elevation has been determined as the distribution factor for mosquito faunas in other regions (Adoha et al., 2024; Rakotonirina et al., 2023).

Aedes albopictus (16.67%) and *Armigeres subalbatus* (16.67%) were the major significance of these findings where *Aedes albopictus* was known as the vector of pathogenic viruses such as dengue, chikungunya, yellow fever, and Zika which can cause life-threatening disease in human (Ahebwa et al., 2023). As for *Armigeres subalbatus*, it was known as the vector of zoonotic *Brugia pahangi* filariasis (Intarapuk et. al.; Muslim et al., 2013).

The main limitations of this study include the fact that each site was visited only once due to logistical constraints, and only two sampling methods—the Human Landing Catch (HLC) technique and the Daytime Resting Collection—were employed. Conducting multiple sampling visits and utilizing a wider variety of traps at the study sites would likely enhance both the diversity and density of mosquito fauna collected (Rakotonirina et al., 2023). In addition, about 11.90% of the specimens were slightly damaged due preservation method in the field. Thus, the identification can only be done until the genus level. Meanwhile, 9.52% of the specimens, *Aedes*, cannot be identified due to the lack of references of mosquitoes from Sabah.

CONCLUSION

Based on this study, it can be concluded that Marai Parai has a high diversity of mosquitoes. Four genera were successfully identified from 42 individual adult mosquitoes; *Aedes*, *Anopheles, Armigeres*, and *Culex*. For the *Aedes* genus, there are three recorded species (*Aedes aegypti*, *Aedes albopictus, Aedes* sp.), including one group of unknown species (*Aedes* sp.). For *Anopheles*, there are two recorded species (*Anopheles aitkenii, Anopheles* spp.), including a group of unknown species (*Anopheles* spp.). *Armigeres* is the most diverse genus with four species were successfully recorded (*Armigeres giveni*, *Armigeres moultoni*, *Armigeres* spp., *Armigeres subalbatus*), including a group of unknown species (*Armigeres* spp.). Whereas, for the genus *Culex*, three species were successfully recorded (*Culex pseudosinensis, Culex quinquefaciatus, Culex* spp.), also including a group of unknown species (*Culex* spp.).

The mosquito diversity was different at each of the campsites' elevations. The diversity of the mosquitoes was higher at the elevation of 1,215 m above sea level (Nunuk Subcamp), but the least at the elevation of 880 m above sea level (Kg Kiau Nuluh Basecamp). At the elevation of 1,652 m above sea level, no mosquito was recorded (Marai Parai Subcamp).

The abundance of *Aedes albopictus* and *Armigeres subalbatus*, the main vectors for several tropical diseases at Marai Parai, must be highlighted in the management plan for mitigation purposes. These finding is a solid foundation to kick start a surveillance program to monitor these pathogenic vectors to reduce the health impact not only on the villagers, but also the tourists at Marai Parai.

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