PROCEEDINGS OF THE HEART OF BORNEO (HOB) SARAWAK SEMINAR 2023:

THE SCIENTIFIC EXPEDITION TO GERENAI-LONG MEKABA, SARAWAK

12TH-13TH OCTOBER 2023
WATERFRONT HOTEL, KUCHING










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Forests Department Sarawak

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ON
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Stephen P. Teo, Angel Kho, Aurelia Dulce Chung, Julia Sang, Habibah binti Salleh and Hajah Mohizah binti Mohamad

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FOREWORD



The Heart of Borneo (HoB) Initiative which was officially launched in Brazil on 27th March, 2006 is a transboundary cooperation between three countries; Brunei, Indonesia and Malaysia on a voluntary basis that share the same vision of conservation and environmental protection while enhancing sustainable development that improves the welfare and livelihood of the communities involved. On 12 February 2007 the Minister of Natural Resources and Environment, Malaysia; the Minister of Forestry, Republic of Indonesia and the Minister of Industry and Primary Resources, Brunei Darussalam, jointly signed and issued a Declaration in Bali, Indonesia. The HoB initiative is fully in line with existing state and federal government policies.

In Sarawak, the HoB area initially straddles an area of 2.1 million hectares but was later expanded to a further 2.689 million ha over a contiguous block along Sarawak's boundaries with Kalimantan and Brunei as well as the neighbouring state of Sabah. The HoB area covers various forest resources and conservation of a network of protected areas, productive forests and other land uses with the objective to effectively manage them for sustainability and posterity.

As part of the HoB Sarawak activities, a scientific expedition was organised to the Long Mekaba FMU area in 2023. The proceedings presented here are the culmination of a scientific expedition to the Long Mekaba FMU in Baram, Sarawak in 2023 and hereby report the various studies done during the duration of the expedition. The results from the studies reveal the wealth and diversity, as well as for their impacts on the environment and the socio-economic status of the rural communities within the area.

The proceedings encompass eclectic topics that are covered under the 5 pillars of the Heart of Borneo ranging from the environment such as biodiversity, ecotourism and so forth to traditional knowledge as well as forest management. Documentation of such knowledge will be useful and vital for sustainable development, particularly in the Heart of Borneo area.

Last but far from least, I wish to extend my sincere appreciation to all the staff of the Forest Department, especially the International Affairs Division (IAD), participants and all the agencies of both the scientific expedition as well as the seminar concerned for ensuring the success of the programme.

DATU HAJI HAMDEN BIN HAJI MOHAMMAD
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Day 1
12th October 2023

FOREST CONDITION OF THE RIVER BUFFER ZONE IN SELECTED SARAWAK PERMANENT FOREST ESTATE

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Abstract: As required in Malaysian Criteria & Indicator (2020) for sustainable management of natural forests, forest management practices should conserve and protect biological diversity, water resources, soils, and fragile ecosystems to maintain ecological functions. In Sarawak Permanent Forest Estate (PFE), the buffer zones reinforce the protection of conservation areas, networks of rivers, vulnerable habitats, and water catchment areas. While buffer zones are often recommended for protection and conservation within PFE, they have rarely been systematically studied in Sarawak, especially the river buffer zones. Lack of information on the effectiveness of river buffer zones causes a setback for better sustainable forest management since ineffective river buffers will endanger the vulnerable ecosystem of rivers while threatening the quality of river water and aquatic life. This paper shares the preliminary findings of the existing river buffer condition in selected forest management units of Sarawak.

Keywords: Conservation, buffer zone, river, forest management.

1 INTRODUCTION

River vegetation is a critical habitat and provides essential forest services for the freshwater ecosystem. In Sarawak's timber production forest, a certain width of the riparian forest is set aside for protection and demarcated as a river buffer zone to mitigate the logging impact. Logging activities are mainly in the Permanent Forest Estate (PFE) and PFEs cover 30% of Sarawak's total landmass. The riverbank forests and water quality are interconnected. The condition of riparian forests significantly influences the quality of water. Studies have shown that maintaining good water quality is linked to the condition of the riparian zone (Osborne & Kovacic 1993).

Healthy riparian forests ensure their ecological function. In Malaysia, riparian forests or banks are recognized as important zones for water management and be managed by retention of existing vegetation or replanting (if degraded) with native species (DID, 2012). Riparian forests control erosion by stabilizing the banks, filtering nutrients and pollutants delivered from the uplands, and controlling water temperature and light (Tiwari et. al., 2016). The water quality

of the Sarawak rivers has decreased over the years (Mohammad Razi et al., 2021). Some studies have proved that anthropogenic activities such as logging having an impact on the riverbank ecosystems, simultaneously affect the river water. Logging creates forest canopy gaps which results in a higher sedimentation rate (Ling et al., 2016).

Scientific studies on the Sarawak riparian forest are scarce. Lack of information on the condition of riverbank forest reserves causes a setback for better sustainable forest management since ineffective forest buffers will affect river water quality. Therefore, a study is conducted to find out the condition of our riparian forests. The objectives of this study are (1) to determine the species composition of the riparian forest stands at selected PFE areas; (2) to assess the forest stand structure of the riparian vegetation at selected PFE areas, and (3) to assess the impacts of logging on riparian forests.

2 METHODOLOGY

1. Study Area

Study sites were selected for the riparian forests on five rivers in Sarawak's permanent forests. The riparian forests comprise the logged-over, primary, and protected forests in Anap Muput FMU, Raplex FMU and Gerenai FMU (Figure 1).



Figure 1: The location of the study sites

2.2 Plot Establishment

Seven (7) permanent plots of 0.25-ha size with 25 m width and 100 m length were established across different conditions at the 5 rivers with different attributes shown in Table 1. The purpose of establishing the plot permanently is to monitor changes in the river buffers. The selection of plots was in a randomly stratified manner to ensure representation of the forest categories.

Table 1: Attributes of the plots

FMU	River name	Plot	Forest Category
Gerenai	Sg. Silat Mekaba	1	No logging
Raplex	Sg. Mia	2,3	Logged, No logging
Raplex	Sg. Lily	4	Logged
Anap Muput	Sg. Kebalang	5,6	Logged, No logging
Anap Muput	Sg. Ayam	7	Logged

3. Plot Assessment

There are 20 subplots in each permanent plot. Assessment of the subplots moved in a zig-zag fashion. Sampling intensity was 100% for trees with diameter at breast height (DBH) of 10 cm and above. The parameters collected were the tree species, DBH, tree height (total and merchantable), bole form, canopy form, and climber presence. Trees were identified at the species level. For the enumerated trees with incomplete botanical names, leaf specimens were collected and further identified at the Sarawak Herbarium. All measured trees were tagged and labelled with their consecutive number.

4. Data and Statistical Analysis

Tree species composition and diversity were calculated based on the species occurrences from the sample plots. Species diversity value was determined using the Shannon-Weiner Index. Forest stand's structure where the diameter classes of trees were tabulated. A T-test analysis was performed to compare changes in species composition between primary and logged forests. The same analysis was also performed to study the tree stand occupancy and structure between different forest categories.

3 RESULTS AND DISCUSSION

1. Tree Species Composition

A total of 984 standing trees were enumerated from the seven sample plots. Of these numbers, it comprises 55 families, 114 genera, and 244 species. The five dominant families recorded in the river buffer zone are the Dipterocarpaceae, Euphorbiaceae, Myrtaceae, Malvaceae, and Moraceae. A comparative analysis with other studies was made as shown in Table 2. Shannon

Wiener's index of logged forests shows a higher value compared to no-logging riparian forests. Other studies stated that later successional forest communities commonly exhibit higher species diversity (Lei et al. 2009), thus any disturbed forests will harbour more records of species.

Table 2: Comparison of the Shannon-Weiner Index of the river buffer zone plots with other studies.

Study	Land Use	Family	Genus	Species	Shannon-Weiner Index
Current finding	**No logging forest**	**43**	**85**	**173**	**4.27**
Current finding	**Logged forest**	**45**	**89**	**144**	**4.5**
Zani, et. al. (2013)	No logging forest (primary)	43	104	184	3.38
Fitri, et. al. (2020)	Logged forest	34	79	124	4.19

3.2 Tree Stand Distribution

The stem density by diameter classes distribution is an inversed J curve for logging and no-logging riparian forests (Figure 1). Commonly, uneven-aged tropical forests have diameter distributions representing all age classes in a reversed-J-shaped curve (Hitimana, 2004). This shows that logged riparian forests in the studied area still hold the natural stand structure of a forest.

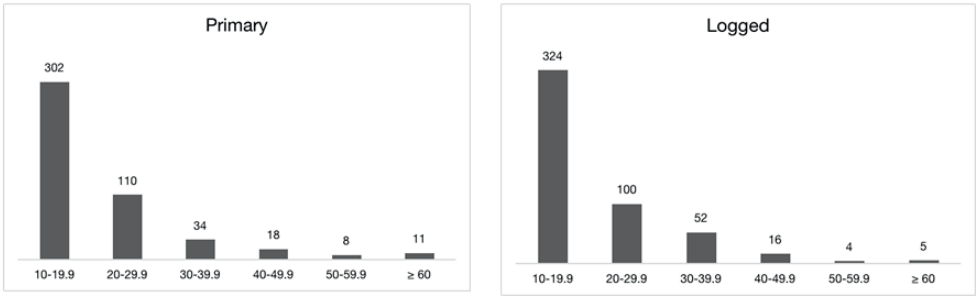


Figure 1: Inversed-J curve for primary and logged-over riparian forests

There is no significant difference in the diameter class distribution for both the control (no logging) and logged over riparian forests (Table 3). The smaller diameter of trees comprises more species. Results show that as the diameter classes increase, there is a decrease in the

number of species. Species richness, abundance, and spatial diversity indices decreased in a typical inverted J-shape pattern with the increasing diameter classes (Li et al., 2023).

Table 3: Percentage of stand frequency for primary and logged-over river buffer zones

	Percent (%) frequency of stands in each forest category	
Diameter Classes (cm)	**Primary**	**Logged over**
10 – 19.9	62.5	64.7
20 – 29.9	22.8	20
30 – 39.9	7.0	10.4
40 – 49.9	3.7	3.2
50 – 59.9	1.7	0.8
≥ 60	2.3	1.0

3.3 Tree Stands Area Occupancy

Primary riparian forests have higher basal area per hectare and tree density compared to logged forests (Table 4). It implies that logging activities had an impact on the tree occupancy and stem density of the forests. Changes in forest structure could affect the surrounding ecological function. The diversity of stand structure, resulting from the recruitment of different-sized trees into the dynamic forest strata affects the productivity of forest ecosystems (Jingjing, 2007). Riparian forests play an important role as natural filters to protect the river water quality. The diversity of tree size and multi-layered canopies affects the amount of light and precipitation received by lower trees and understory plants (Anderson *et al.*, 1969).

The occupancy of stands enables the understanding of the distribution, density, and spatial patterns of the existing tree stands within the riparian forests. The occupancy of trees is still higher (bigger basal area and tree density) for the control (no-logging riparian forests). Some studies revealed that human disturbances decrease big-sized trees and forest functioning (Poulsen et al., 2020). However, the two-tailed P value for tree occupancy and tree density gave the result of higher than α (>0.005); therefore, the primary and logged-over riparian forests are equal.

Table 4: Summary of basal area and stem density per hectare.

Subject	Primary Forest	Logged Over
Basal area per hectare (m^2/ha)	22.46	19.96
Tree density (tree/ha)	644	501

3.4 Species Abundance

Primary and logged-over riparian forests show different distributions and compositions of dominant species. Both categories only shared three dominant species as shown in Table 5. The primary forest recorded more dipterocarps as the dominant species (*Rubroshorea parvifolia*, *R. pinanga*, *R. beccariana*, *R. myrionerva* and *R. sagittata*), whereas logged-over forests recorded only three species from the dipterocarps (*Rubroshorea myrionerva*, *R. macrophylla* and *R. pinanga*). The variance of species composition for both forest categories shows that disturbance to forests affects the species composition. Kariuki (2006) stated that the regeneration of forests is correlated with disturbance intensity. The direct impact of logging on forests is on tree diversity and composition, where the diversity would commonly decline along a logging gradient (Burivalova, 2014).

Table 5: Composition of dominant species for primary and logged-over forests

No logging (primary)	Logged over
1. *Macaranga hosei* **	
2. *Rubroshorea parvifolia*	1. *Rubroshorea myrionerva* **
3. *Teijsmanniodendron bintuluense*	2. *Rubroshorea macrophylla*
4. *Rubroshorea pinanga* **	3. *Macaranga hosei* **
5. *Garcinia parvifolia*	4. *Rubroshorea pinanga* **
6. *Strobocalyx arborea*	5. *Duabanga moluccana*
7. *Rubroshorea beccariana*	6. *Elateriospermum tapos*
8. *Rubroshorea myrionerva* **	7. *Pternandra azurea*
9. *Rubroshorea sagittata*	8. *Urophyllum congestiflorum*
10. *Alangium javanicum*	9. *Alstonia scholaris*
	10. *Artocarpus kemando*

** sharing dominant species

3.5 Forest Stands Structure

Bole form and canopy form were assessed to evaluate the quality of the physical stand structure of riparian forests. Although species diversity is important in the ecosystem, stand structure attributes are equally important in forest function. The results revealed that logged forests gave a higher percentage of good bole form and primary forests gave a higher percentage of good canopy form (Table 6). However, both the two-tailed P values for the bole form analysis equal 0.0775 and the two-tailed P value for the canopy form equals 0.7510 ,thus indicating that the results are statistically not significant and the forest structure for both forest categories are assumed to be equal.

Table 6: Summary of bole form and canopy form quality

Bole Form	Straight to slightly bend	Bend to deform	% Good form
No logging	339	144	70.2
Logged	418	82	83.6
Canopy Form	**Full to 75%**	**50% to broken top**	**% Good form**
No logging	295	136	68.4
Logged	250	250	50

3.6 Mitigating Measures for Harvesting Operation

The p-value is higher than alpha ($\alpha = 0.05$) for forest stand structure and tree occupancy, thus this indicates that all plots in the primary & logged forests are statistically not significant and assumed to be equal. It shows that there are no drastic changes in the tree composition and stand structure in the studied areas. So, what does this indicate? It shows that measures to protect the riparian forest in the timber production forest are in place. The timber license holder and FMU management complies with the State regulations and standard of procedure for river buffer management. There are two standards for river buffer management available for Sarawak, viz. Reduced Impact Logging (RIL) Guidelines and Department of Irrigation and Drainage (DID) standards. The river buffer zones are protected areas in the PFE; thus, logging activities are forbidden.

4 CONCLUSION

Preliminary findings show that there is no significant difference between logging and no logging area (control) for the riparian vegetation within the niche of the PFE conditions after logging. The composition of tree species between logging and primary forests does not change significantly, but there were more records of the light-demanding species for the logging area. Basal area, tree density, and the individual tree form are statistically not significant, thus forest structure for both forest categories is assumed to be equal. Nevertheless, species diversity and variation of the individual tree size are crucial for ecosystem functions. Tree diversity and a wide range of stem sizes could influence the efficiency of resources and utilization among and within component species in forests. Therefore, there is a need for a current evaluation of the effectiveness of buffer zones to improve measures to reduce the impacts of logging and ensure the protection of the ecology of the rivers.

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Abstract: Gerenai FMU in Sarawak has actively experienced selective logging activities since the early 1990s, resulting in the depletion of valuable timber species. An estimated 80% of the forest in the Gerenai FMU is classified as mixed dipterocarp forest (MDF). The objective of our study was to document tree species diversity and soil physicochemical properties of remnant MDF stands in two selected forest trails in Long Mekaba, Gerenai FMU, Sarawak. A 150 m x 10 m belt transect was established at each trail in which all trees with diameter at breast height (DBH) of 10 cm and above were measured and identified. At each transect, 10 soil samples were collected for analysis of pH and total nitrogen and phosphorus concentrations. Soil variables did not differ significantly between the two transects ($P > 0.05$). We recorded a total of 135 and 128 trees within the belt transects established in the MDFs of Trail 10 (Trail A) and Trail 11 (Trail B), respectively. Trees in the forest of Trail A comprised 28 families, while the forest of Trail B comprised 25 families. The forest in Trail A was dominated by the Dipterocarpaceae family, which included 19 individuals of *Dryobalanops becarii* and 20 individuals of *Shorea* sp. (*S. agami, S. parvifolia, S. poteiensis, S. rubra* and *Shorea* sp.) In contrast, the forest in Trail B was dominated by the Rubiaceae family, which included 24 individuals of *Timonius* sp. and 14 individuals of *Neonauclea* sp. Overall, our current results showed that total stem density and basal area were higher in the forests of Trail A than in those of Trail B although the differences were not significant. The tree community composition differed between the two transects. Our results highlight the high conservation value of mixed dipterocarp forests in Long Mekaba, although this study requires further replication in terms of the number of transects and study sites.

Keywords: high conservation value, mixed dipterocarp forests, selective logging, species diversity, timber species

1 INTRODUCTION

Tropical rainforests are the most biodiverse terrestrial ecosystem in the world (LaFrankie *et al*., 2006; Demies *et al*., 2019; Ganivet *et al*., 2020) as they are known to harbour the world's most species-rich communities. Human activities such as logging and forest conversion are two major threats to biodiversity of tropical rainforests (Sodhi *et al*., 2004; Ganivet *et al*., 2020). Previous studies by Achard *et al*. (2002) and Sodhi *et al*. (2004) reported Southeast Asia as recording one of the highest deforestation rates within the tropical regions. Forest fragmentation caused by logging has continued to increase in many parts of the tropics and often described as one of the most important causes of global species declines and extinctions (Ouborg *et al*., 2006). In this context, documenting the biodiversity of pristine tropical rainforests with no logging history, in terms of tree species diversity is crucial for conservation planning. This is especially important for tropical forests located close to areas that are actively experiencing selective logging (Demies *et al*., 2019).

In Sarawak, mixed dipterocarp forests (MDF) are considered as one of the major forest types, the most complex floristically, and comprise of both the lowland and hill dipterocarp forests which extends from sea level to 750 m (Ashton, 1995; Demies *et al*., 2019). The trees in MDFs are characterized as tall trees (35 to 60 m heights), with deep and very dense canopy. The most dominant tree family in MDF is from the Dipterocarpaceae family. The floristic diversity of MDF in Sarawak have previously been elaborated extensively by Whitmore (1972) and Ashton (1988). To date, approximately 80% of the Malaysian Borneo forests, regardless of the forest types, have been impacted by logging (Bryan *et al*., 2013; Ganivet *et al*., 2020).

The Gerenai Forest Management Unit (FMU) consists of different forest types which includes MDF, heath forests and others and comprising about 158,614 ha of land area. The FMU areas are also considered as production forests and some known parts of the forests have undergone multiple cycles of selective logging. About 48% (71,227 ha) of this FMU is within the Heart of Borneo Corridor. Trees with diameter breast height (dbh) 36 cm $\geq$ 40 cm were selected for logging and these included some valuable timber species, such as *Anispotera* sp., *Cotylelobium* sp., *Dialium* sp., *Dipterocarpus* sp., *Dryobalanops* sp., *Eusideroxylon* sp., *Gonystylus* sp., *Intsia* sp., *Shorea* sp., *Tristaniopsis* sp., *Upuna* sp., and *Vatica* sp. (Marsden, 2020). In the logged-over areas of Gerenai FMU, these species are depleting in numbers, further impacting forest structure and species composition, and resulting in declining forest productivity. To determine the status of the forests in Gerenai FMU as an essential step towards its conservation, we focused on assessing tree diversity differences and quantifying soil physicochemical properties between two MDFs in Long Mekaba.

The main aim of our study was to investigate floristic patterns of the tree communities within the remnants MDFs in Long Mekaba in response to selected soil variables. We focused on three research questions: (1) Do soil properties differ between two transects? (2) Do measures of forest structure (stem diameter and basal area) and tree floristic diversity differ between transects? (3) Is differentiation of tree floristic patterns associated with underlying differences in soil variables?

2 METHODOLOGY

1. Study area

This study was conducted during the Sarawak Heart of Borneo (HoB) Scientific Expedition in Long Mekaba, Gerenai FMU, Ulu Baram Miri Sarawak, from 12th to 25th August 2022. This scientific expedition was organized by Sarawak Forestry Department, which aimed to document the richness of flora and fauna at Long Mekaba, Gerenai FMU area to create awareness for local communities in conserving the biodiversity of the area. The study was conducted in an intact tropical rainforest located within the Gerenai FMU (2°54 57.4'N, 114° 56 10.1'E), in Ulu Baram Miri, Sarawak, Malaysia (Figure 1). The mean annual rainfall in Ulu Baram ranges from 1371 to 3654 mm (Vijith & Dodge-Wan, 2020; METMalaysia, 2022) and average temperature of about 24 – 31°C. The dominant vegetation in the study area is mainly MDF.

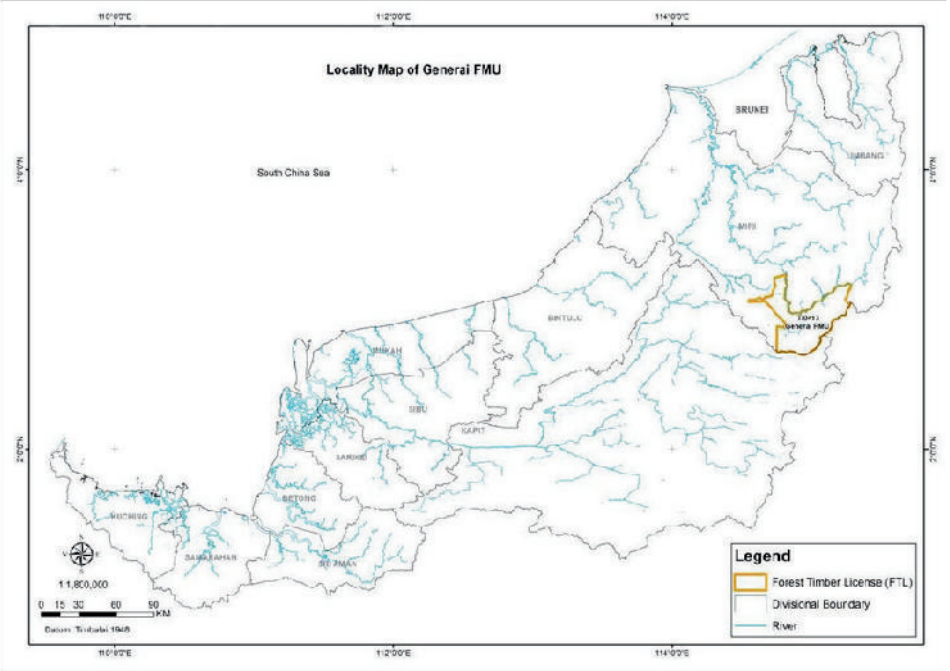


Figure 1. The map of Gerenai FMU, Ulu Baram Miri, Sarawak, Malaysia. (Map credit: Sarawak Forestry Department).

A total of 16 accessible trails within a 4800-ha land area (Figure 2) were established by the expedition organizers from the Sarawak Forestry Department since mid-2022 as part of the expedition preparation. Each trail ranged from 100 m to 2 km in length, cutting through forests, rivers, and streams. Out of the 16 available trails, we selected two trails located 2 km apart from each other, with elevations of 321 m and 292 m respectively, and set up our transect lines.

Two belt transects measuring 150 m x 10 m (approximately 0.3 ha in total) were established in the areas of Trail 10 (Trail A; 2°54'57.40"N 114°56'10.10"E) and Trail 11 (Trail B; 2°54'37.70"N 114°55'45.90"E; Figure 2). These sites were described as pristine MDF (Mixed Dipterocarp Forest) by the HoB secretariats and the local people of Long Mekaba. They have

been utilized by the local communities for resources, and thus far, no logging activities have been conducted in these two selected sites. The elevation of Trail A ranges from 283 m to 323 m, while in Trail B it ranges from 259 m to 292 m above sea level.

Each 150 m transect was subdivided into fifteen 10 m x 10 m subplots, and soil samples were collected from one random point within each subplot (n = 15 samples from one transect line) at a depth of 0 cm to 15 cm using a handheld scoop. The soil samples were air-dried in the shade for at least one week at the expedition camp before further analysis. Approximately 10 g of the dried soil samples were used to determine soil pH (Allen *et al.*, 1989). The remaining soil samples were ground using a mortar and pestle, sieved through a 250 µm sieve, and further ground using a ball mill (Mixer Mill, MM400, Retch, Germany) to obtain fine soil samples for soil nitrogen (N) and phosphorus (P) concentration analysis. The concentrations of total N and P were determined using the Kjeldahl method by digesting each soil sample in concentrated H_2SO_4 and analyzed using a Flow Injector Analyzer (FIAstar 5000, Höganäs, Sweden).

Within each transect, all trees with a diameter at breast height (DBH) of ≥ 10 cm were tagged using acrylic paint, measured for DBH using a diameter tape (Metri, Germany), and identified to species level. Voucher specimens for the censused trees were collected for taxonomic confirmation, which took place at the Brunei National Herbarium (BRUN). Trees were mapped within the 10 m x 10 m subplot, and their locations within these subplots were recorded using a GPS device (Garmin GPSMAP 62s, Taiwan). We determined the size class distributions of trees based on DBH for each transect. Trees with a DBH of more than 40 cm were classified as "large trees" (Chave *et al.*, 2005; Din *et al.*, 2015).

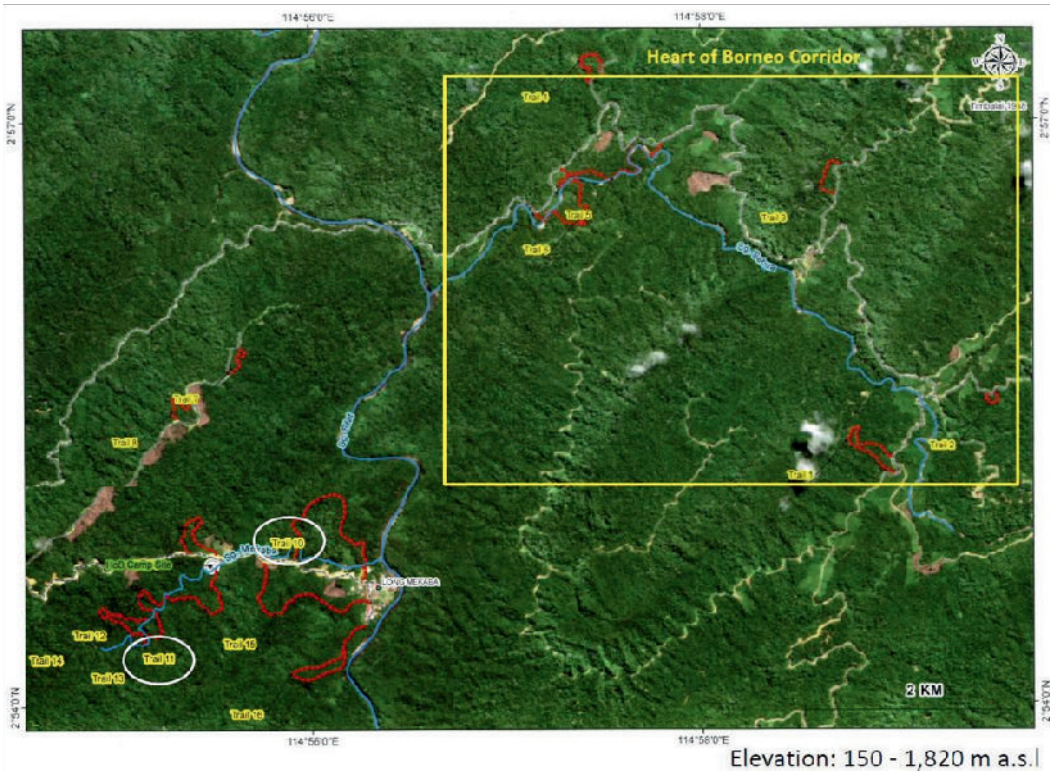


Figure 2. A total of 16 accessible trails within a 4800-ha land area were set up by the expedition organizer from the Sarawak Forestry Department. Each trail stretched from 100 m – 2 km which cuts through forests, rivers, and streams. (Map credit: Yazid Kalbi)

2.2 Statistical analysis

The basal area of each tree was calculated using the equation by Avery & Burkhart (2015): basal area (B.A.) = $\pi(DBH/2)^2$, and the total basal area (m^2) was then calculated for each transect. All statistical analyses were conducted using R version 4.2.2 (R Core Team, 2022). Three diversity indices were determined for each transect: Shannon's index, evenness, and the inverse Simpson's index using the R vegan package version 2.6-4 (Oksanen, 2022) in R 4.2.2 (R Core Team, 2022).

The effects of Trail (A vs. B) on the mean tree abundance, mean species richness, mean diversity indices, and soil properties were explored through separate linear mixed-effects (LME) models using the nlme version 3.1-137 package in R 4.2.2 (R Core Team, 2022). Trails (A or B) were modelled as fixed effects, and subplots were fitted as random effects. The effects of Trails were separately analyzed using LME on the following variables: (1) pH and concentrations of total nutrients (total N and P in mg g^{-1}) of soil samples, (2) mean DBH (cm) and mean basal area (cm^2), (3) species richness, abundance, Shannon's index, evenness, and the inverse Simpson's index. Assumptions of normality and homogeneity of variances were tested via the Residual versus Fitted plot and QQ-plot functions in R and were not violated.

Non-metric multi-dimensional scaling (NMDS) ordination was conducted using presence-absence data and the Jaccard index (Legendre & Legendre, 2012) to explore variations in tree species communities within the two transects in relation to soil pH and concentrations of total N and P in the soil. This analysis was performed using the R vegan package version 2.6-4 (Oksanen, 2022). To determine the floristic similarity between the two transects, we conducted PERMANOVA (Anderson, 2001) using the adonis function in the R vegan package version 2.6-4 for presence-absence data, following Draper *et al.* (2019). Additionally, the function *pairwise.adonis* was used to conduct pairwise comparisons following PERMANOVA (Martinez Arbizu, 2020).

3 RESULTS

1. Differences in soil properties between trails

Comparisons of the soil properties between the two trails are provided in Table 1. Soil pH, Total N and Total P concentrations did not significantly differ between the two trails.

Table 1: Soil variables (mean ± SE) in transects set up at the two different trails. *F* and *P* values from a linear mixed effects (LME) model are shown for each variable.

Trail	pH	Total N (mg g^{-1})	Total P (mg g^{-1})
A	4.16 ± 0.11	2.60 ± 0.27	0.23 ± 0.01
B	4.13 ± 0.11	2.31 ± 0.15	0.24 ± 0.01

F value	0.039	0.545	0.778
P value	0.845	0.467	0.385

3.2 Variation in diameter, basal area and size class distributions

A total of 263 individual trees ≥ 10 cm DBH were censused in the two 150 m transects. Both mean DBH and the mean basal area of trees were not significantly different between transects (P > 0.005; Table 2). Size class distributions based on DBH differed between transects. Small-sized trees with DBH of 10 - 20 cm were most abundant in both transects, while trees with DBH of 20 – 30 cm were more abundant in Trail B than Trail A (Figure 3). Large trees of DBH ≥ 40 cm were more abundant in Trail A compared to Trail B (Figure 3).

Table 2: Mean diameter at breast height (DBH), mean basal area, and total basal area of trees in transects set up at the two different trails. The total basal area of a study trail was calculated from the sum of basal areas of all trees within the transect. *F* and *P* values from a linear mixed effects (LME) model are shown for each variable.

Trail	Mean DBH (cm)	Mean basal area (cm^2)	Total basal area (m^2)
A	24.8 ± 1.41	722.3 ± 115.7	108.35
B	22.1 ± 0.93	494.6 ± 59.2	74.18
F value	2.696	3.050	-
P value	0.112	0.092	

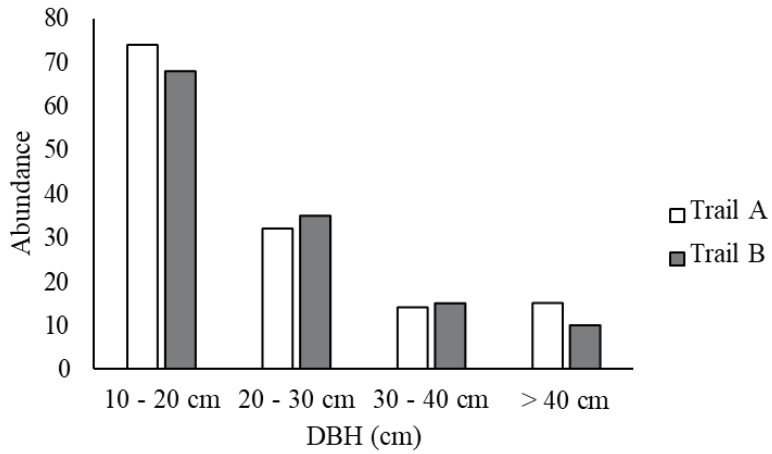


Figure 3. Size class distribution of trees in different DBH (cm) classes in transects set up at the two different trails. Trees with DBH greater than 40 cm were classified as large trees.

3.3 Tree species richness and diversity

A total of 102 tree species with a diameter at breast height (DBH) of ≥ 10 cm were recorded in the two transects, representing 40 families and 65 genera. Among these, 67 (66%) tree species were identified to the species level, while 35 (34%) were identified only to the genus level. In Trail A, 135 individual trees of 56 species were recorded, whereas in Trail B, 128 trees of 55 species were recorded. The most abundant species in Trail A was *Dryobalanops beccarii* Dyer (n = 19), while in Trail B, it was *Timonius* sp. (n = 22; see Table A1). The family Rubiaceae was the most species-rich (n = 10 species, 45 trees), followed by Lauraceae (n = 8 species, 15 trees), Dipterocarpaceae (n = 6 species, 39 trees), and Myrtaceae (n = 6 species, 10 trees). Among the Rubiaceae species recorded within the two transects were Ixora *griffithii* Hook., *Neonauclea artocarpoides* Ridsdale., *Neonauclea cyrtopoda* (Miq.) Merr., *Neonauclea* sp., *Pleiocarpidia paniculata*, *Porterandia* sp., *Rothmannia* sp., *Tarenna cumingiana* (S.Vidal) Elmer., *Timonius borneensis* Valeton., and *Timonius* sp. (Table A1). The mean species richness, abundance, Shannon's index, evenness, and Inverse Simpson's index did not show significant differences between the two transects (Table 3).

Table 3: Species richness, abundance, Shannon's index, evenness, and inverse Simpson's index of trees in transects set up at the two different trails. Values are mean ± SE. *F* and *P* values from a linear mixed effects (LME) model are shown for each variable.

Trail	Species richness	Abundance	Shannon's index	Evenness	Inverse Simpson's index
A	6.67 ± 0.68	9.00 ± 0.68	1.73 ± 0.12	0.94 ± 0.02	5.75 ± 0.68
B	6.53 ± 0.63	8.53 ± 0.77	1.71 ± 0.12	0.94 ± 0.02	5.58 ± 0.63
F value	0.021	0.206	0.014	0.082	0.020
P value	0.887	0.653	0.906	0.777	0.889

3.4 Differences in floristic diversity between transects

The NMDS ordinations revealed a clear separation of tree species according to the two transects, indicating highly varied tree community composition in the MDF of Long Mekaba (see Figure 4). Distinct clustering of tree species and transects was observed in the NMDS ordination, based on presence-absence data, for Trails A and B. In Trail A, the species *Syzygium villamilii* (SYZY.VILL) stood out as the only species clearly distinct from the others. Total phosphorus (P) concentrations emerged as the most influential soil variables affecting tree community composition in both transects (Table A2). Specifically, total P concentrations correlated significantly with *Fagraea ridleyi* (FAGR.RIDL) in Trail A and *Monocarpia marginalis* (MONO.MARG) in Trail B, though not significantly in either Trail A or B.

Analysis of the Venn diagram generated from all recorded species (Figure A1) revealed that only nine species co-occurred in both transects, Trails A and B. These species include

Artocarpus odoratissimus, *Crypteronia griffithii*, *Dillenia suffruticosa*, *Garcinia* sp., *Baccaurea* sp., *Litsea* sp., *Neonauclea* sp., *Pternandra cogniauxii*, and *Pternandra crassicalyx*. The species codes for Figure 4 and the full species checklist are provided in Supplementary Appendix 1 (Table A1). Results from PERMANOVA indicated significant differences in tree species communities between Trails A and B ($F = 3.68$, $R^2 = 0.12$, $P < 0.001$; see Table 5).

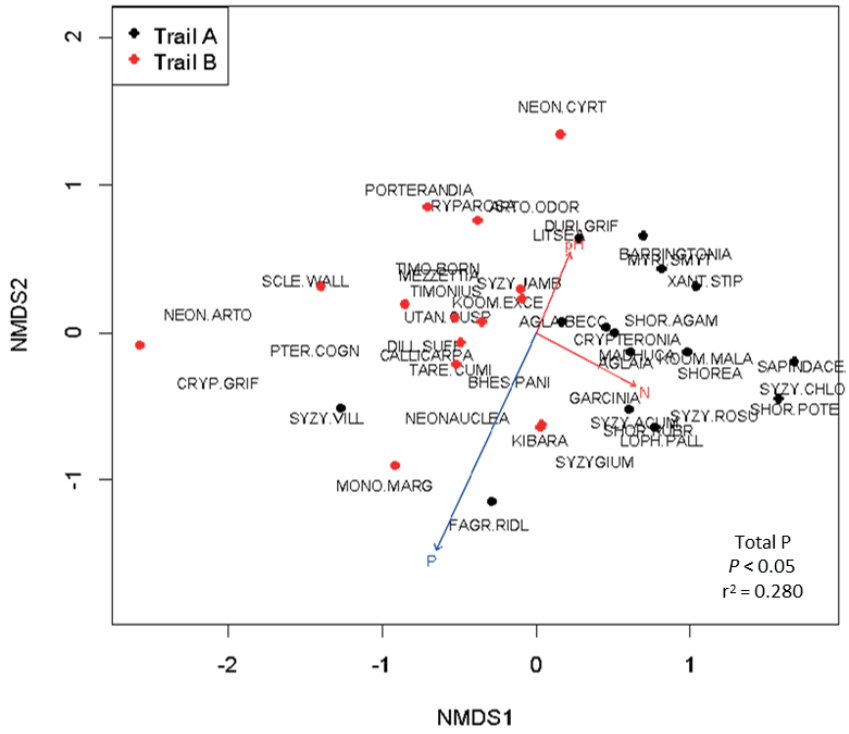


Figure 4. Nonmetric multidimensional scaling (NMDS) ordination for tree species at the transects set up at the two different trails, using presence-absence data and the Jaccard index, in relation to soil variables. Different colours denote the two different transects in Trail A (n = 15 subplots) and Trail B (n = 15 subplots). The direction of the arrow indicates the most rapid change of that variable while the length of the arrow is proportional to the strength of the correlation. Arrows for pH and N (in red) are not significant, while the arrow for P (in blue) was significant when soil variables were fitted onto NMDS ordination.

Table 5: Pairwise PERMANOVA test results, based on presence-absence data, to show pairwise differences in tree community composition between transects: Trail A vs Trail B. The PERMANOVA for presence-absence data was significant at $p < 0.001$ with R^2 of 0.09. ** indicates significant differences at $P < 0.01$.

Pairwise comparison	F	R^2	P
Trail A vs Trail B	3.68	0.12	0.001**

4 DISCUSSION

There was no significant variation in soil physicochemical properties (soil pH, total N and P concentrations) between the two transects in Trail A and B. The range of pH values recorded (4.13 – 4.16) is consistent with those from other Bornean MDFs (Sukri *et al*., 2012; Jaafar *et al*., 2016; Tripathi *et al*., 2016; Jaafar *et al*., 2022). Total N concentrations recorded in this study was 12% and 30% higher than what reported by Sukri *et al*. (2012) and Jaafar *et al*. (2016), but 15% lower than what was reported by Tripathi *et al*. (2016). Additionally, the total P concentrations from the two transects in this study were 33% much higher than reported by Jaafar *et al*. (2016) in the primary MDF in Brunei Darussalam but similar to what was reported by Sukri *et al*. (2012) within the clayed MDFs of Belalong. Differences between our study and others conducted within Borneo can be attributed to differences in parent materials from the two different countries (Fujii *et al*. 2011; Sellan *et al*., 2021) although occurring in the same island of Borneo. MDFs are known to occur on different soil types, including both sandy and clay soils (Sukri *et al*. 2012). These variations in soil properties can influence species distributions and composition (Lee *et al*., 2002; Sukri *et al*. 2012), hence the differences we observed in this current study between the two transects.

Our study has shown that the overall tree abundance recorded in Trail A (n = 135) and Trail B (n = 128) MDFs in Long Mekaba, Gerenai FMU, Ulu Baram Miri, Sarawak is much lower compared to records reported by Demies *et al*. (2010), Vilma *et al*. (2012), and Demies *et al*. (2019). By estimation, the number of trees per hectare for our current study is approximately 450 trees, which is about 70%, 58%, and 62% lower than that reported in Bukit Jugam (Demies *et al*., 2010), Bukit Mina (Vilma *et al*., 2012), and Anap Muput (Demies *et al*., 2019). We recommend that transect replications in both Trail A and Trail B in our study site are needed to document the current stands of trees in the study area.

Overall, the most species-rich family recorded in this study was Rubiaceae. However, Trail A in this current study was dominated by the Dipterocarpaceae family, which is a typical pattern of Bornean forests (Ashton, 1988), while the non-dipterocarp family, Rubiaceae, dominated Trail B. *Shorea* was the dominant genus in terms of species richness in Trail A, consistent with findings by Lee *et al*. (2002) in the Lambir 52-ha plot. The number of Dipterocarpaceae individuals reported in this study was notably higher (29%) than what has been reported by Davies and Becker (1992; 8 - 18%) and Ganivet *et al*. (2020; 25%). This could be partly due to differences in total sampling area between studies. The existence of these Dipterocarpaceae families is significant as trees from this family are usually valuable timber resources in Borneo (Hayward *et al*, 2021; Widiyono, 2021) and considering that the area studied is just within 4 – 5 km away from selective logging areas, conserving these trees is of the highest priority. In decreasing order of the total number of individual trees, the second most represented families in both Trail A and B were the Lauraceae, with the dominant genus being *Litsea* sp. (n = 7). This contradicts findings by Lee *et al*. (2002), Ling and Sang (2012), and Ganivet *et al*. (2020), which reported the second most representative families in Sarawak MDFs were the Euphorbiaceae family.

The differences in dominant families and genera observed in the two trails were supported by the significant PERMANOVA results, despite the trails being located only two km apart. Significant differences in tree species composition were also observed for habitats that were only 800 m apart from each other by Lee *et al*. (2002) within the 52-ha plot at Lambir.

Differences in tree communities within MDFs are likely due to habitat differences in terms of edaphic conditions (Ganivet *et al*., 2020). For our study, the significant influence of soil P content on tree communities within Trail A and Trail B, as shown by our NMDS results, is consistent with the known importance of P in driving tree community compositions within Borneo (Paoli *et al*. 2006; Sukri *et al*. 2012). Additionally, other soil properties such as gravimetric water content and soil texture, as well as other environmental parameters such as elevation, slope, topography, air temperature, humidity, canopy openness, litter depth, and soil temperature, may be influential upon tree communities (Thammanu *et al*., 2021) but were not recorded in the present study.

Both sites are known to have not been logged before, but since Trail B in this study is very close to the civilization area, it is possible that the local communities in the area used this site for other purposes before they regenerated naturally into a forest. The dominance of Rubiaceae in Trail B, with 45 individuals (35% of all trees in Trail B), indicated that MDFs within Trail B may have experienced more disturbance from the local community access to the forest here. Additionally, we acknowledge the potential effects of dispersal mechanisms in determining species distributions in the two transects. The absence of parent Dipterocarpaceae trees in Trail B could potentially be one of the main reasons for the observed differences in species compositions compared to Trail A. Dispersal mechanisms have been shown to influence tree communities in tropical rainforests (Cannon & Leighton, 2004).

Our study has shown that mixed dipterocarp forests that are located in areas that have been subjected to logging and other uses do carry significant value for conservation. Given that deforestation remains a major threat to the forests of Malaysian Borneo (McAlpine *et al*., 2018; Chapman *et al*., 2020), it is imperative for studies to be conducted by ecologists and conservationists in different forest uses as well as the remaining unlogged forests in this region.

5 RECOMMENDATION

To improve future studies, additional transect replications across the study area are recommended. This will provide a more accurate assessment of tree abundance and community composition, capturing spatial variability effectively. Conservation efforts in the MDFs of Long Mekaba should be intensified to preserve biodiversity hotspots. These forests host a diverse range of tree species, including valuable timber resources such as those from the Dipterocarpaceae family. Urgent measures are needed to protect these ecosystems from further degradation, especially given their proximity to selective logging areas. Implementing strict conservation measures, including establishing protected areas and community-based initiatives, can help ensure the long-term sustainability of these forests.

Furthermore, comprehensive studies are required to understand the ecological dynamics of these forests, considering both biological and environmental factors. Future research should focus on unraveling the intricate relationships between tree species composition, soil properties, and environmental variables. Advanced analytical techniques such as remote sensing and GIS mapping can provide valuable insights into landscape-scale patterns of forest structure and function. By fostering interdisciplinary collaborations and employing innovative methodologies, we can enhance our understanding of MDF ecosystems and develop effective conservation strategies tailored to their unique characteristics.

6 CONCLUSION

This preliminary study is deemed critically important and calling for the protection of unlogged forests in Long Mekaba, Gerenai FMU, Ulu Baram Miri Sarawak. Our results highlight the current high conservation value of forests in MDF, especially the Trail A, which houses a considerably high number of Diptercaropaceae families, representing the most valuable timber species in this region.

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APPENDIX

Table A1: Full checklist of censused tree species (DBH ≥ 10 cm) across the transects set up at Trail A (n = 15 subplots) and Trail B (n = 15 subplots). Values are total tree abundance for each species recorded per trail. Superscript labels indicate the conservation status of the species according to the IUCN Red List (LC - Least Concern, NT - Near Threatened, VU - Vulnerable, EN – Endangered) (IUCN 2020).

No.	Family	Species	Species Code	Trail A	Trail B
1	Achariaceae	*Ryparosa* sp.	RYPAROSA		1
2	Anacardiaceae	*Buchanania sessifolia*^{LC}	BUCH.SESS		1
		Campnosperma auriculatum^{LC}	CAMP.AURI		1
3	Annonaceae	*Mezzettia* sp.	MEZZETTIA		3
		Monocarpia marginalis	MONO.MARG		1
4	Apocynaceae	*Alstonia iwahigensis elmer*	ALST.ELME	1	
5	Burseraceae	*Canarium littorale*^{LC}	CANA.LITT	1	
		Canarium pilosum	CANA.PILO		1
		Canarium sp.	CANARIUM	2	
6	Cannabaceae	*Gironniera subaequalis*^{LC}	GIRO.SUBA	1	
7	Celastraceae	*Bhesa paniculata*^{LC}	BHES.PANI		3
		Lophopetalum pallidum	LOPH.PALL	1	
8	Clusiaceae	*Garcinia beccarii*	GARC.BECC		1
		Garcinia sp.	GARCINIA	2	4
9	Crypteroniaceae	*Crypteronia glabriflora*	CRYP.GLAB	1	
		Crypteronia griffithii	CRYP.GRIF	2	1
		Crypteronia sp.	CRYPTERONIA	5	
10	Dilleniaceae	*Dillenia suffruticosa*	DILL.SUFF	1	6
11	Dipterocarpaceae	*Dryobalanops beccarii*^{EN}	DRYO.BECC	19	
		Shorea agami^{NT}	SHOR.AGAM	9	
		Shorea parvifolia^{LC}	SHOR.PARV	1	
		Shorea poteiensis	SHOR.POTE	1	
		Shorea rubra^{NT}	SHOR.RUBR	2	
		Shorea sp.	SHOREA	7	
12	Ebenaceae	*Diospyros foxworthyii*	DIOS.FOXW		1
13	Elaeocarpaceae	*Elaeocarpus clementis*^{LC}	ELAE.CLEM		1
14	Euphorbiaceae	*Baccaurea* sp.	BACCAUREA	6	5
		Glohidion sp.	GLOHIDION		1
		Macaranga hosei	MACA.HOSE		1
15	Flacourtiaceae	*Flacourtiaceae*	FLACOURTIACEAE	2	
16	Gentianaceae	*Utania cuspidata*	UTAN.CUSP		1
17	Guttiferae	*Cratoxylum cochinchinense*^{LC}	CRAT.COCH		1
		Cratoxylum sp.	CRATOXYLUM		1
18	Ixonanthaceae	*Ixonanthes reticulata*	IXON.RETI		1
19	Lameaceae	*Callicarpa glabrifolia*^{LC}	CALL.GLAB		1
		Callicarpa sp.	CALLICARPA		4

20	Lauraceae	*Cinnamomum endlicheriaecarpum*	CINN.ENDL	1	
		Eusideroxylon melangangai	EUSI.MELA		2
		Lauraceae sp.	LAURACEAE	1	
		Litsea cylindrocarpa[LC]	LITS.CYLI		1
		Litsea megacarpa[LC]	LITS.MEGA	1	
		Litsea sp.	LITSEA	2	5
		Phoebe grandis[LC]	PHOE.GRAN	1	
		Potoxylon sp.	POTOXYLON		1
21	Lecythidaceae	*Barringtonia lanceolata*	BARR.LANC		1
		Barringtonia revoluta	BARR.REVO	1	
		Barringtonia sp.	BARRINGTONIA	3	
22	Leguminosae	*Koompassia excelsa*	KOOM.EXCE		2
		Koompassia malaccensis	KOOM.MALA	7	
23	Loganiaceae	*Fagraea ridleyi*	FAGR.RIDL	1	
		Fagraea sp.	FAGRAEA	1	
		Norrisia maior	NORR.MAIO		1
24	Malvaceae	*Durio griffithii*	DURI.GRIF	1	
		Durio sp.	DURIO	1	
25	Melastomaceae	*Plethiandra* sp.	PLETHIANDRA		3
		Pternandra cogniauxii	PTER.COGN		1
		Pternandra crassicalyx	PTER.CRAS	1	2
		Pternandra sp.	PTERNANDRA		1
26	Meliaceae	*Aglaia beccarii*	AGLA.BECC	1	
		Aglaia sp.	AGLAIA	4	
27	Monimiaceae	*Kibara* sp.	KIBARA		1
28	Moraceae	*Artocarpus elasticus*[LC]	ARTO.ELAS		1
		Artocarpus kemando	ARTO.KEMA		1
		Artocarpus odoratissimus[NT]	ARTO.ODOR	1	1
		Artocarpus sp.	ARTOCARPUS	7	12
29	Myristicaceae	*Horsfieldia grandis*[LC]	HORS.GRAN	1	
		Knema sp.	KNEMA		1
		Myristica cinamomea	MYRI.CINA	1	
		Myristica smythiesii	MYRI.SMYT	1	
		Myristica sp.	MYRISTICA		1
30	Myrsinaceae	*Ardisia* sp.	ARDISIA	7	
31	Myrtaceae	*Syzygium acuminatissima*	SYZY.ACUM	1	
		Syzygium chlorathum	SYZY.CHLO	2	
		Syzygium jambos[LC]	SYZY.JAMB		1
		Syzygium rosulentum	SYZY.ROSU	2	
		Syzygium villamilii	SYZY.VILL	1	
		Syzygium sp.	SYZYGIUM	3	
32	Oleaceae	*Chionanthus curvicarpus*	CHIO.CURV	1	
		Chionanthus sp.	CHIONANTHUS	1	
33	Phyllanthaceae	*Baccaurea kunstleri*	BACC.KUNS		2
		Baccaurea reticulata	BACC.RETI	1	

34	Polygalaceae	*Xanthophyllum stipitatum*	XANT.STIP	1	
		Xanthophyllum sp.	XANTHOPHYLLUM	4	
35	Putranjivaceae	*Drypetes* sp.	DRYPETES	1	
36	Rubiaceae	*Ixora griffithii*	IXOR.GRIF		1
		Neonauclea artocarpoides	NEON.ARTO		2
		Neonauclea cyrtopoda	NEON.CYRT		1
		Neonauclea sp.	NEONAUCLEA	2	11
		Pleiocarpidia paniculata	PLEI.PANI		1
		Porterandia sp.	PORTERANDIA		1
		Rothmannia sp.	ROTHMANNIA		1
		Tarenna cumingiana	TARE.CUMI		1
		Timonius borneensis	TIMO.BORN		2
		Timonius sp.	TIMONIUS		22
37	Rutaceae	*Meliscope hookeri*	MELI.HOOK		1
38	Santalaceae	*Scleropyrum wallichianum*[LC]	SCLE.WALL		1
39	Sapindaceae	*Nephelium uncinatum*[LC]	NEPH.UNCI	1	
		Nephelium sp.	NEPHELIUM	2	
		Sapindaceae sp.	SAPINDACEAE	1	
40	Sapotaceae	*Aulandre longifolia*	AULA.LONG	1	
		Madhuca sp.	MADHUCA	1	
		Palaquium rivulare[LC]	PALA.RIVU		1
	Total number of species recorded			102	
	Total number of trees recorded per trail			135	128
	Total number of species recorded per trail			56	55

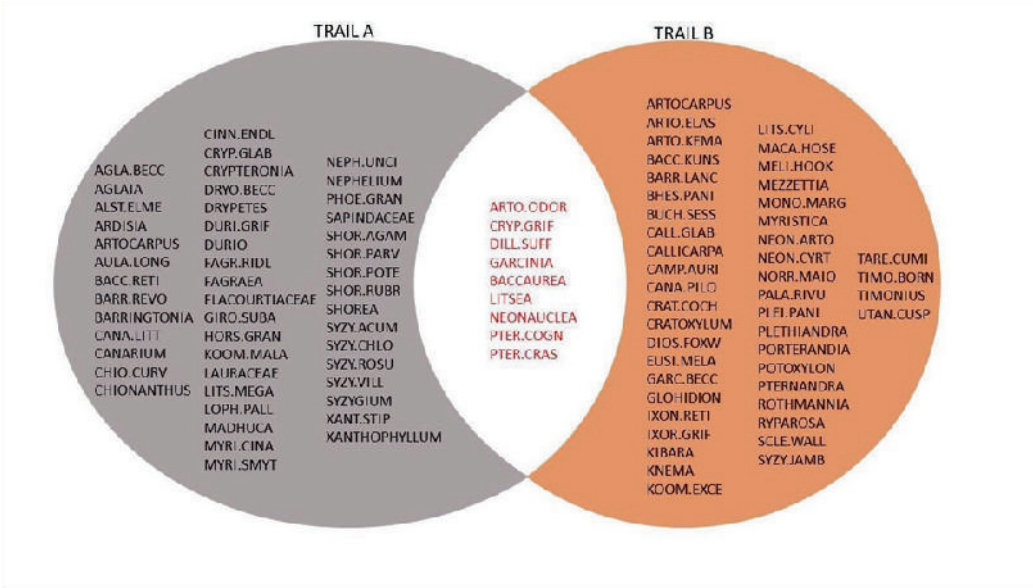


Figure A1. Venn-diagram to illustrate the distribution of tree species recorded across the two trails A and B (n = 15 subplots each). Species codes and their definitions are listed in Table 6.

Table A2: Fits of soil properties onto NMDS ordination, based on presence-absence data using Jaccard index, of tree species across transects set up at Trail A (n = 15 subplots) and Trail B (n = 15 subplots). r^2 values indicate the correlation coefficient denoting the strength of the correlation with p-values assessed using 1000 permutations. Significant p-values are highlighted in bold.

Properties	Code in NMDS	r^2	p-value
Soil pH	pH	0.037	0.592
Total N	N	0.060	0.432
Total P	P	0.280	**< 0.05***

WATER QUALITY PATTERN OF NATURAL AND LOGGED-OVER FOREST CATCHMENTS AT GERENAI-LONG MEKABA, SARAWAK

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Abstract: This study compares and quantifies the physico-chemical quality of surface water in natural and logged-over forests at Gerenai-Long Mekaba area. Selected physico-chemical parameters such as pH, temperature, conductivity, dissolved oxygen, total dissolved solids, turbidity, ammoniacal nitrogen, total suspended solids and chemical oxygen demand were taken based on a total of 42 samples based on 14 sampling stations during the Sarawak Heart of Borneo (HoB) Gerenai-Long Mekaba Scientific Expedition on 12-25 September 2022. The mean values of these parameters were compared and classified according to the National Water Quality Standards for Malaysia (NWQS). This expedition's results showed a significant difference (p-value ≤ 0.05) between natural and logged-over forests in terms of pH, conductivity, turbidity, total dissolved and suspended solids. The water quality of the logged-over forest catchment deteriorates after a rainfall event where the suspended solids and turbidity are the most affected parameters. The ideal buffer zone distance between the harvesting sites and streams must be identified to minimize the rate of sediment movement into the water. However, the NWQS indicated that the logged-over forest catchment in the present study is still in good quality, probably because logging activities have ceased in that area for over a few years and some water quality parameters have started to return to their original state.

Keywords: Water quality, physico-chemical parameters, logged-over forest catchments

1 INTRODUCTION

Forest and water are highly important resources that provide many socioeconomic functions and services to human societies and the environment. In remote areas of Sarawak, where treated water supply is unavailable, often drinkable raw river water became the only solution for consumption. However, the disturbance of forests modifies and alters the stream discharge, chemical quality, and physical properties of water (Neal *et al*., 2003). Water quality can be affected by many factors such as deforestation, active land development, and land conversion (Harun *et al*., 2015).

Meanwhile, according to Barbara *et al.* (2004), the greatest potential for reducing water quality on forested catchments come from roads on steep slopes, erodible soils, and stream crossings. Their research shows that 90% of the sediment that ends up in the water from forested areas was associated with improperly designed and maintenance of logging roads. This situation was further aggravated by the intensity and frequency of rainfall recorded within the study area.

Maintaining good quality stream water is of paramount importance for aquatic ecosystems that require specific parameters such as dissolved oxygen levels, temperature, and pH. Poor water quality can lead to habitat degradation and a decline in biodiversity. Tolerable water quality ensures that habitat viability to support a diverse range of species. Many fishes, invertebrates, and plants rely on dissolved oxygen in the water to survive. Low dissolved oxygen levels can lead to hypoxia or anoxia, which can be fatal for aquatic life. Sudden water temperature changes or excessively high temperatures may affect the metabolic rates of aquatic organisms lead to stress or even kill aquatic organisms. Extreme pH levels also can be harmful to aquatic life as highly acidic conditions may injure fish, amphibians, and invertebrates.

Hence, this study was conducted to determine the effect of post-logging activities on surface water quality. Next, surface water quality status at natural and logged-over forests was compared and assessed based on the National Water Quality Standards (NWQS).

2 MATERIALS AND METHODS

1. Study area

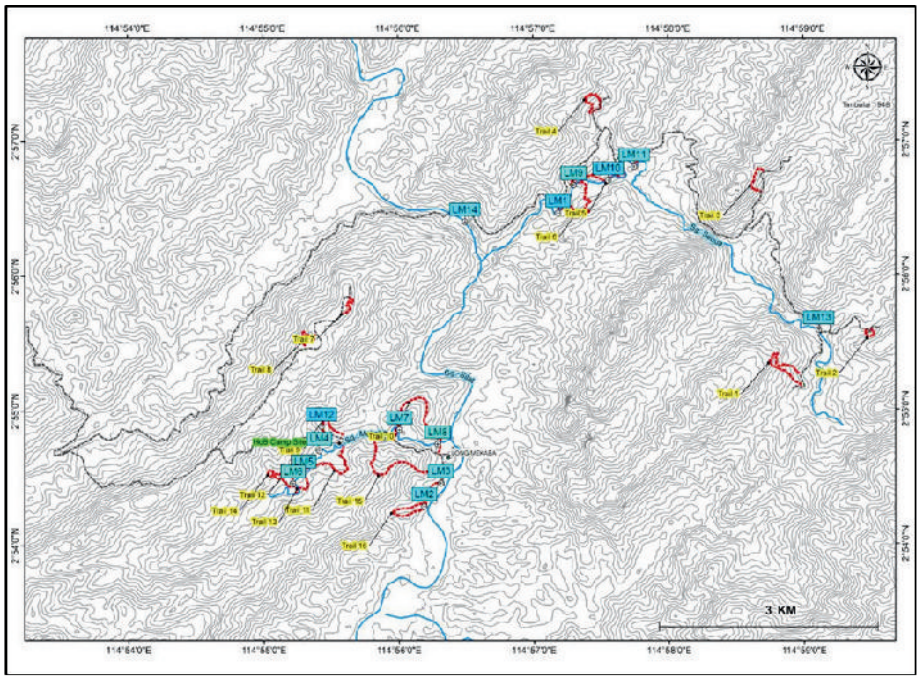
This study was conducted during the Sarawak Heart of Borneo (HoB) Scientific Expedition Gerenai-Long Mekaba from 12th to 25th August 2022. Long Mekaba is part of the Gerenai Forest Management Unit (FMU) and situated at the Batang Baram-Sg. Silat area in Miri Division. It has common boundaries with the Usun Apau National Park and the proposed Sg. Moh Wildlife Sanctuary. The geological features of the FMU landscape ranges from riverside flats that quickly grade into low undulating hills which lead to rugged mountainous terrain with altitudes ranging from 150 to 1,820 meters above sea level. The forest types in the FMU consist of dominant Mixed Dipterocarp Forest, Lower Sub-Montane Forest, Kerangas Forest scattered on sandy terraces, riparian forest along rivers, and secondary or degraded forest.

There are 4 streams involved in this study; namely Sg. Mekaba, Sg. Sebua, Sg. Silat and Sg. Telik Esai. The study location and sampling points are shown in Table 1 and Figure 1.

Table 1: GPS coordinate of the study sampling points

Sampling Point	Streams name	GPS Coordinates		Remarks
		Latitude (N)	Longitude (E)	
LM1	Sg. Sebua	2 56'27.6"N	114 56'26.5"E	Logged-over Forest
LM2	Sg. Telik Esai	2 54'17.2"N	114 56'11.1"E	Natural forest
LM3	Sg. Mekaba	2 54'27.8"N	114 56'18.7"E	Natural forest
LM4	Sg. Mekaba	2 54'42.6"N	114 55'25.0"E	Natural forest
LM5	Sg. Mekaba	2 54'32.3"N	114 55'17.4"E	Natural forest
LM6	Sg. Mekaba	2 54'27.5"N	114 55'12.9"E	Natural forest
LM7	Sg. Mekaba	2 54'51.3"N	114 56'00.2"E	Natural forest
LM8	Sg. Silat	2 54'45.0"N	114 56'17.0"E	Natural forest
LM9	Sg. Sebua	2 56'39.3"N	114 57'18.4"E	Logged-over Forest
LM10	Sg. Sebua	2 56'41.8"N	114 57'33.0"E	Logged-over Forest
LM11	Sg. Sebua	2 56' 48.0"N	114 57' 44.7"E	Logged-over Forest
LM12	Sg. Mekaba	2 54' 52.9"N	114 55' 25.5"E	Natural forest
LM13	Sg. Sebua	2 55' 35.4"N	114 59' 06.1"E	Logged-over Forest
LM14	Sg. Sebua	2 56' 23.9"N	114 56' 29.4"E	Logged-over Forest

Figure 1: Sampling station



2.2 METHODOLOGY

A total of 14 sampling stations were chosen based on accessibility and homogeneity in order to obtain a representative sample (natural and logged-over forests). The logged-over area that has been selected for water sampling is a post-logging area that has ceased the logging activities in 2020.

A total of nine (9) water quality parameters were assessed namely; pH, temperature, dissolved oxygen, conductivity, total dissolved solids, turbidity, ammonia nitrogen, chemical oxygen demand, and total suspended solids.

A multi-instrument parameter Lovibond was used to measure pH, temperature, dissolved oxygen, conductivity, and total dissolved solids. Meanwhile, Handheld Turbidimeter Lovibond was used to measure turbidity reading and ammonia nitrogen was detected by using the HACH test kit.

Water samples were collected and brought back to the laboratory for further analyses which involve parameters like chemical oxygen demand (COD) and total suspended solids (TSS). COD was tested by using COD Vario Photometer Lovibond; meanwhile, TSS were analysed following the Standard Methods (APHA, 1998).

The results of water quality in the study area were then classified based on the National Water Quality Standard (NWQS), which consists of six classes (I, II, III, IV, and V) of water quality in accordance with the highest beneficial uses attainable in each class. NWQS is an important standardisation measurement that is most helpful in assessing and monitoring surface water (Yisa & Jimoh, 2010).

Statistical analysis software (SAS) was used to perform the statistical analyses T-Test to determine and compare the mean of each parameter for natural and logged-over forests.

3 RESULTS AND DISCUSSION

Physico-chemical stream water parameters refer to various physical and chemical characteristics that are measured to assess its quality and suitability for various purposes such as human consumption and the health of aquatic ecosystems. These parameters provide valuable information about the composition and condition of water.

The results of selected physico-chemical water parameters are summarized in Table 2 and from the results, the mean values for natural and logged-over forests were calculated and shown in Figure 2.

Sampling station		pH	Temp. (°C)	Conductivity (µs)	DO (mg/L)	TDS (mg/L)	Turbidity (NTU)	NH_3N (mg/L)	TSS (mg/L)	COD (mg/L)
LM1	(LO)	6.60±0.17	25.4±0.06	14.30±0.15	7.40±0.06	9.17±0.10	104.03±5.69	0.0±0	60.60±0.12	4.5±0.12
LM2	(N)	6.94±0.12	24.7±0	17.20±0.10	7.10±0.10	11.01±0.07	3.75±0.85	0.0±0	1.80±0.03	0.0±0
LM3	(N)	6.86±0.12	25.2±0	21.56±0.25	7.30±0.06	13.81±0.16	2.54±0.69	0.0±0	6.33±0.02	0.0±0
LM4	(N)	7.19±0.08	24.0±0	26.50±0.20	7.80±0	16.97±0.13	3.07±0.86	0.0±0	3.67±0.01	3.0±0.06
LM5	(N)	6.65±0.04	24.2±0.12	32.00±0.10	7.30±0.06	20.49±0.07	2.09±0.37	0.0±0	1.33±0.12	0.0±0
LM6	(N)	6.64±0.01	24.8±0	24.60±1.46	7.80±0.25	15.73±0.93	5.02±0.89	0.0±0	5.33±0.05	0.0±0
LM7	(N)	6.87±0.06	24.5±0	27.03±0.21	7.90±0.17	17.30±0.13	11.29±2.96	0.0±0	16.33±0.08	2.0±0.06
LM8	(N)	6.93±0.03	25.2±0	26.70±0.35	7.97±0.21	17.11±0.23	8.46±0.42	0.0±0	3.00±0.03	0.0±0
LM9	(LO)	6.75±0.09	24.5±0.06	19.93±0.42	7.80±0.10	12.76±0.27	54.96±8.68	0.0±0	29.33±0.12	0.0±0
LM10	(LO)	6.26±0.04	25.6±0	20.50±0.12	7.80±0.26	13.15±0.08	69.12±1.75	0.0±0	33.33±0.03	1.0±0.17
LM11	(LO)	6.23±0.07	23.5±0	12.10±0.15	7.60±0.12	7.74±0.11	131.40±4.12	0.0±0	99.67±0.06	3.0±0.06
LM12	(N)	6.26±0.03	23.6±0	15.40±0.15	8.30±0.17	9.86±0.62	4.28±0.22	0.0±0	5.67±0.18	0.0±0
LM13	(LO)	6.21±0.04	25.4±0	13.30±0.20	7.80±0.25	8.51±0.76	45.70±22.46	0.0±0	33.33±0.57	0.0±0
LM14	(LO)	6.44±0.01	24.7±0.12	21.10±0.45	7.10±0.21	13.50±0.15	35.02±4.86	0.0±0	25.33±0.10	0.0±0

Table 2: Average water quality parameters in each sampling station

Note: **(N): natural forest; (LO): logged-over forest**

Mean values ± standard deviation

pH is one of the most performed water quality tests and is a measure of the amount of free hydrogen ions in the water and neutral levels have a pH of 7 (Miroslav *et al.*, 2007). The pH of the logged-over forest was ranging from 6.21 to 6.75 meanwhile the natural forest was ranging from 6.26 to 7.19. The difference in pH of logged-over forest (6.41±0.02) and natural

forest (6.79±0.27) was significant at p-value ≤ 0.05 (p-value = 0.0181). Based on the NWQS, natural forest showed an average pH level within class I, meanwhile logged-over forest within class IIA. This showed that there is no sign of acidification of the stream water.

Conductivity is directly related to the amounts of dissolved ions in water. Besides, it is also a measure of water passing an electrical current (Wetzel, 2001). The average conductivity value in natural forest (23.87µs±5.51) was significantly higher than in logged-over forest (16.87µs±4.06) at p-value ≤ 0.05 (p-value = 0.0227). Both natural and logged-over forests showed conductivity within class I.

As a parameter, dissolved oxygen (DO) is also used to measure water quality and shows the amount of dissolved oxygen in a waterbody. There was no significant difference in DO between logged-over forest (7.58 mg/L ± 0.28 mg/L) and natural forest (7.68 mg/L ± 0.40 mg/L) at p-value ≥ 0.05 (p-value = 0.6176). This means that both forests were generally well-aerated and classified under class I, which represents excellent condition of oxygen rate.

Next, the value of total dissolved solids (TDS) in the logged-over forest ranged from 7.74 mg/L to 13.50 mg/L; meanwhile, the natural forest ranged from 9.86 mg/L to 20.49 mg/L. Based on the mean statistical analysis, the difference in TDS of logged-over forest (10.80 mg/L ± 2.60) and natural forest (15.29 mg/L ± 3.53) was significant at p-value ≤

0.05 (p-value = 0.0228). Both logged-over and natural forests were found to be in class I, within the suggested NWQS level. The TDS is one of the important water quality indicators for drinking water and as a general indicator for pollution (Zullyadini *et al.*, 2016).

Turbidity gives an indication of the clarity of water and is influenced by the number of suspended materials in the water (Nguyen & Chai, 2019). The turbidity of the natural forest ranged from 2.09 NTU to 11.29 NTU, and the streams were clear as indicated by the low turbidity. Meanwhile, the logged-over forest showed a high turbidity value, ranging from 35.02 mg/L to 131.4 mg/L. The average turbidity value in the logged-over forest (73.37 NTU ± 37.15) was significantly higher than in the natural forest (5.06 NTU ± 3.20) at p-value ≤ 0.05 (p-value = 0.0002). According to NWQS, natural forest showed an average turbidity level within class I, meanwhile logged-over forest within class IIA and IIB.

Meanwhile, for total suspended solids (TSS), the natural forest recorded the lowest reading (1.33 mg/L). The highest TSS was found at LM 11 (logged-over forest) with a reading of 99.67 mg/L ± 0.06. The average TSS value for logged-over forest (46.93 mg/L ± 28.69) was significantly higher than natural forest (5.43 mg/L ± 4.76) at p-value ≤ 0.05 p-value = 0.0015). Based on the NWQS, natural forest showed an average TSS level within class I, meanwhile logged-over forest within class IIA and IIB.

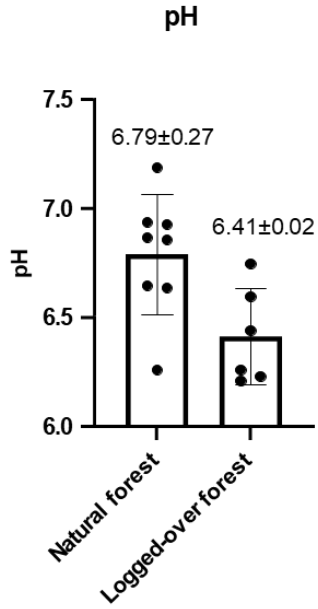
Measurements of water samples collected from natural and logged-over forests showed that the mean chemical oxygen demand (COD) was almost similar and ranged from 0 mg/L (undetected) to 4.50 mg/L. Based on the mean statistical analysis, there was no significant difference in COD between the logged-over forest (1.42 mg/L ± 1.90) and natural forest (0.63 mg/L ± 1.18) at p-value ≥ 0.05 (p-value = 0.3569). Both natural and logged-over forests were classified under class I of NWQS.

The only nutrient parameter tested during this expedition was ammoniacal nitrogen (NH_3N). Ammoniacal nitrogen was determined *in-situ* by using a HACH test kit and based on the

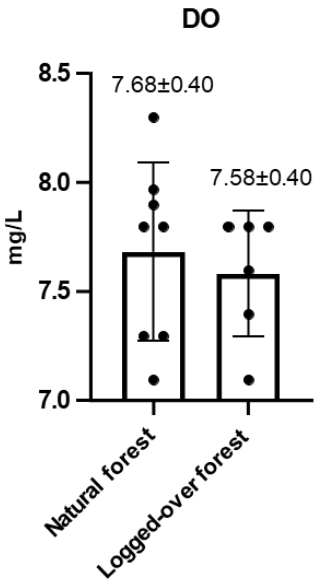
results, both natural and logged-over forests showed no significant pollution with undetected readings (0 mg/L).

Figure 2 compares the results between natural and logged-over forests. These findings revealed that the water quality of undisturbed and natural forest catchment is excellent when compared to water bodies in the logged-over forest. The results from this expedition showed the significant impact of logging on pH, conductivity, turbidity, total dissolved and suspended solids.

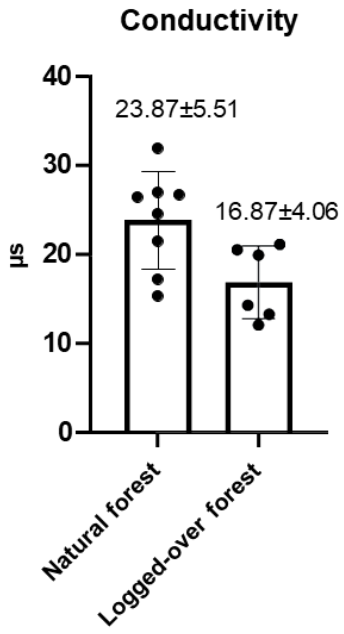
Natural forest catchment tends to provide better stream water quality. The tree canopies are still intact and well-developed with a dense understory of vegetation, including shrubs and ground cover plants. These canopies pattern act as a shield against heavy rainfall that minimizes soil erosion. The roots help to stabilize the soil, reducing the amount of sediment that can be washed into streams during extreme rains or runoff events. The tree roots also play important roles in streambank stability and reduce sediment input to the streams. Indirectly, well-established root systems also help retain nutrients in the soil. The forest floor and litter layer act as a natural filter, slowing down the movement of nutrients like nitrogen and phosphorus from the forest floor to streams. In disturbed forests, where there are often less canopies, leading to higher nutrient runoff and potential water quality issues such as turbidity, total dissolved and suspended solids. Forest canopies also provide shade over streams, helping to maintain stable water temperatures.



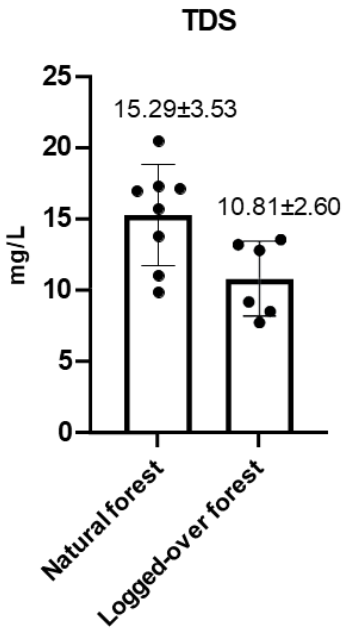
(a) Significant with p-value ≤ 0.05



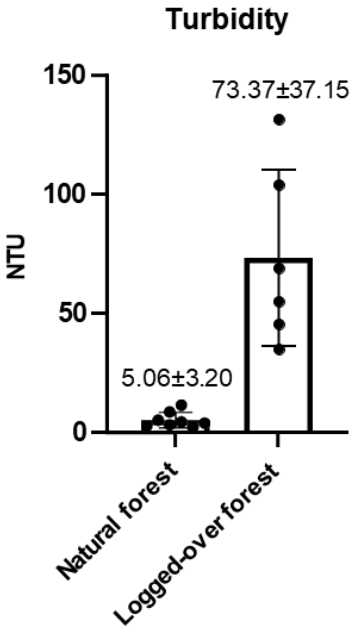
(b) Not significant with p-value ≥ 0.05



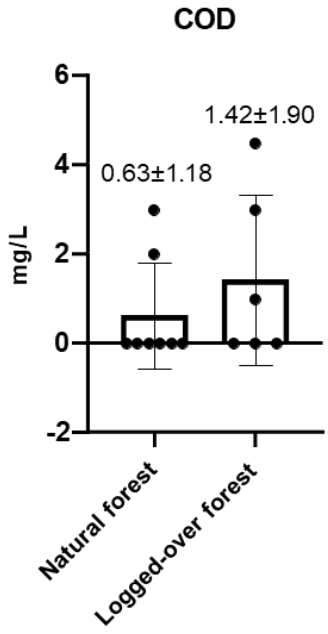
(c) Significant with p-value ≤ 0.05



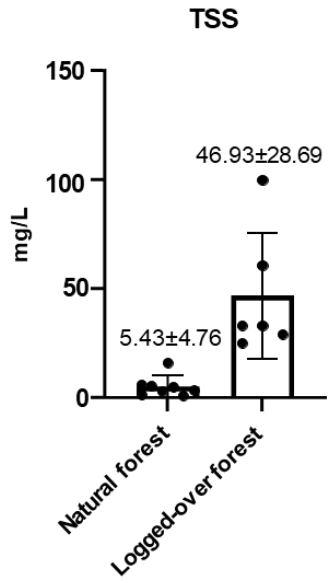
(d) Significant with p-value ≤ 0.05



(e) Significant with p-value ≤ 0.05



(f) Not significant with p-value ≥ 0.05



(g) Significant with p-value ≤ 0.05

Figure 2 (a) – (g): Comparison of physico-chemical readings based on average in the natural and logged-over forests

Logged-over forest in the present study was well-oxygenated with nearly natural pH values. Prior to the rainfall event, the water was quite clear. However, post-logging activities around the expedition study area have impacted the water quality. Turbidity and suspended solids are higher at sampling stations with post-logging activities than at the undisturbed sampling stations. The water quality of the logged-over forest catchment deteriorates after a rainfall event where the suspended solids and turbidity are the most affected parameters. Thus, the ideal buffer zone distance between the harvesting site and streams must be identified to minimize the rate of sediment movement into the water.

Furthermore, one of the goals of sustainable forest management is maintaining water quality. The role of the forest as a catchment area has been disturbed when the harvesting activity operated. During a rainfall event, a higher quantity of surface runoff flowing directly to the nearest stream as less filtering by the tree roots. This contributes to a higher yield of TSS and an increased turbidity value within disturbed catchments. Trees help prevent erosion by directly intercepting rain by laying down a thick mat of litter that protects the soil surface (Friday, 2003). The root acts as a filter to minimize sedimentation entering the stream. The tree root also has the ability to hold the soil and prevent erosion and turbidity in water.

4 CONCLUSION

The findings from this expedition showed a significant difference (p-value$\leq$0.05) between natural and logged-over forests in terms of pH, conductivity, turbidity, total dissolved and

suspended solids. However, the NWQS indicated that the logged-over forest catchments in the present study are still in good quality. This may be due to the fact that logging activities have ceased in that area for more than a few years and some water quality parameters have returned to their original state. In addition, the reduced impact logging (RIL) practices in FMU showed an improvement in water quality status after a few years of operation.

ACKNOWLEDGEMENT

We would like to thank the Director of Forest Department Sarawak for his support and approval of this study. We are also indebted to the Research and Development Division (RDD) staff for their field assistance and the International Affairs Division (IAD) for their support during the expedition.

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ESTIMATING GERENAI-LONG MEKABA FOREST ABOVE GROUND AND BELOW GROUND BIOMASS AT THE LOCATION SCALE

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Abstract: Forest ecosystems are one of the most critical components of terrestrial ecosystems and the largest carbon reservoir. Thus, accurate estimation of forest biomass is prerequisite and basis for trading forest carbon sinks. This study aims at evaluating the above ground and below ground biomass of the Gerenai-Long Mekaba forest during the expedition in September 2022. The above ground biomass includes the standing trees, dead wood, stump, leaf litter and twigs. Whereas the below ground biomass sampling refers to the soil organic carbon. Three circular plots of 250 m^2 were established at Trail 2, 10 and 11 respectively. The diameter at breast height (DBH) of standing trees were measured, leaf litter and twigs were collected and brought back to the laboratory for further processing. Meanwhile, soil organic carbon was determined via auger and core samples.

Keywords: above ground, below ground biomass, DBH

1 INTRODUCTION

Forests sequester and store carbon more than any terrestrial ecosystems. Sarawak, with a landmass of 12.45mil ha where 62% is covered by forests, plays an important role in mitigating climate change. During the expedition in 2022, a forest management unit named Gerenai-Long Mekaba was chosen as the study site. This Gerenai-Long Mekaba site is a secondary forest which is important in determining the country's carbon storage for the REDD+ scheme (Reducing emission from deforestation and degradation in developing countries). There are many uncertainties in the rate of biomass accumulation during the forest regeneration stage, thus it requires more studies to understand the role of Gerenai-Long Mekaba as carbon sink or source. Besides, accurate estimation of small-scale forest biomass is a prerequisite to optimize the allocation of forestry resources.

Above ground biomass could be calculated by several methods, such as harvest method, carbon flux measurements, satellite/remote sensing, modelling or the plot method. The harvest method involves chopping down the trees to calculate the biomass and carbon flux measurements using ecosystem carbon dioxide fluxes to determine the carbon biomass whilst remote sensing made use of Lidar. In this study, the plot method was employed owing to time and cost constraints.

2 MATERIALS AND METHODS

1. Study site

The study was conducted in September 2022 during an expedition at Gerenai Forest Management Unit (FMU) (*latitude* N2°40' to N3°05' and *longitude* E114°32' to E115°20'), which is located within the Long Baram District, Miri Division,Sarawak. It is accessible from Miri by the 111km sealed government road, and then continue to Miri-Bintulu Highway to Tuyut Logpond. It took about 6-7 hours to reach the Silat Camp. The Gerenai FMU is dominated by Mixed Dipterocarp Forest (MDF), Lower Sub-Montane Forest, and Kerangas Forest scattered on sandy terraces, riparian forest along rivers and secondary forest.

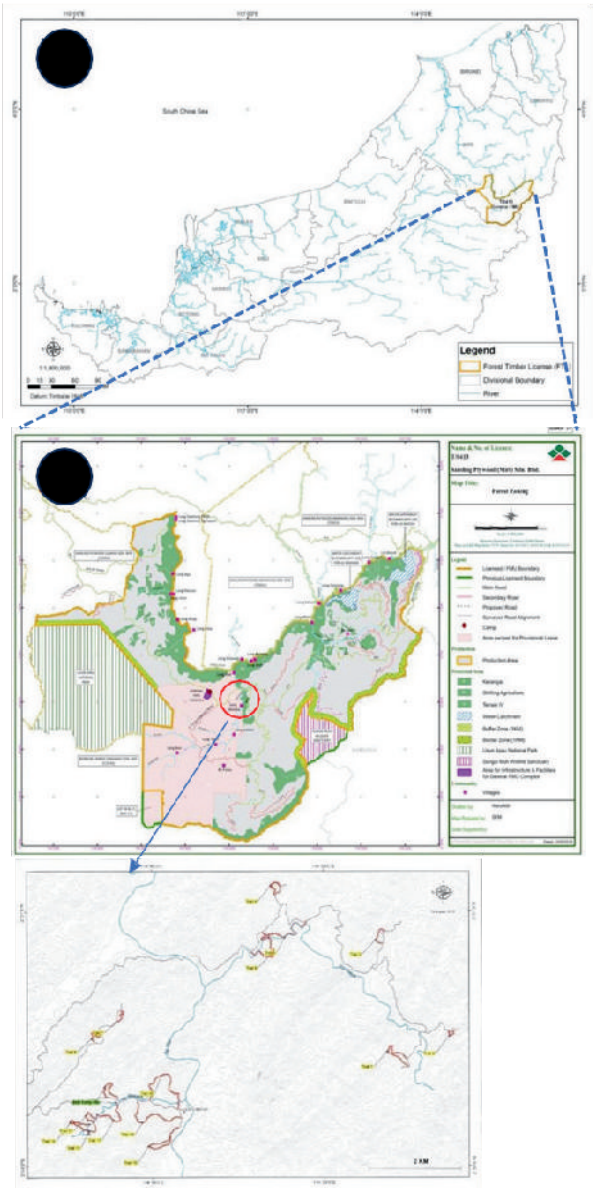


Figure 1. (a) the Sarawak map where Gerenai FMU is located (b) Detail map of Gerenai FMU including forest types (c) a total of 16 trails were constructed during the expedition.

2. Experimental design

Two randomized circular plots were established at Trail 2, 10 and 11 respectively. A Circular plot was chosen over a square plot owing to its simplicity in establishment. The circular plots were divided into sub-circular of $100m^2$ and 250 m^2.

3. Equation for carbon stock estimation

Generally, using local allometric regression equation for estimating biomass is an ideal choice. However, to achieve this objective, we shall need to sample enough trees to represent the size and species distribution (Brown, 2002). However, this is not feasible for this short expedition duration. Hence, a generic biomass equation for moist forest suggested by Chave et al. (2005) was selected. Only DBH data was used to calculate the plant biomass because measuring the height of trees in this study plot was extremely difficult as the top of emergent trees can hardly be seen. The equation used in this study is as follows:

$$AGB = \rho \times \exp(-1.499 + 2.148 \ln(DBH) + 0.207(\ln(DBH))^2 - 0.0281(\ln(DBH))^3)$$

Where AGB is in kg $tree^{-1}$, DBH is in cm. Wood density used is 0.58

4. Aboveground biomass (AGB)

Plants of diameter at breast height (DBH) of less than or equivalent to 5cm were measured in $100m^2$ circular plot whereas plants of more than 5cm were recorded within a $250m^2$ circular plot. Besides standing trees, the dead woods lying on the ground within $250m^2$ circular plot were measured too. As for twigs and leaf litters, they were collected from the $100m^2$ circular plot. The total weight of the leaf litters was recorded and later on sub-sampling of 100g was sent to the laboratory for drying and weight determination.

5. Belowground biomass (BGB)

Belowground component consists of soil and roots. During this expedition, only soil samples were collected via core and auger method. Core ring soil samples were first used to determine the soil bulk density by drying and weighing process. This was followed by ashing 5 grams of oven dried sample in a furnace at 1000° degree celsius to determine the organic matter content. This ashing method is recognised as loss of ignition.

The carbon in the soil was calculated using this equation:

Carbon in soil = Bulk density x depth x carbon content from ashing method

3 RESULTS

More than half of the trees measured in study plot were less than 10cm in diameter. Only one tree in T11 was found to have the biggest diameter of 90.5cm (Figure 2). When comparing between the trails, T11 had more trees with 0-10cm diameter, followed by T10 and T2. However, this trend is reversed for 10-20cm diameter trees.

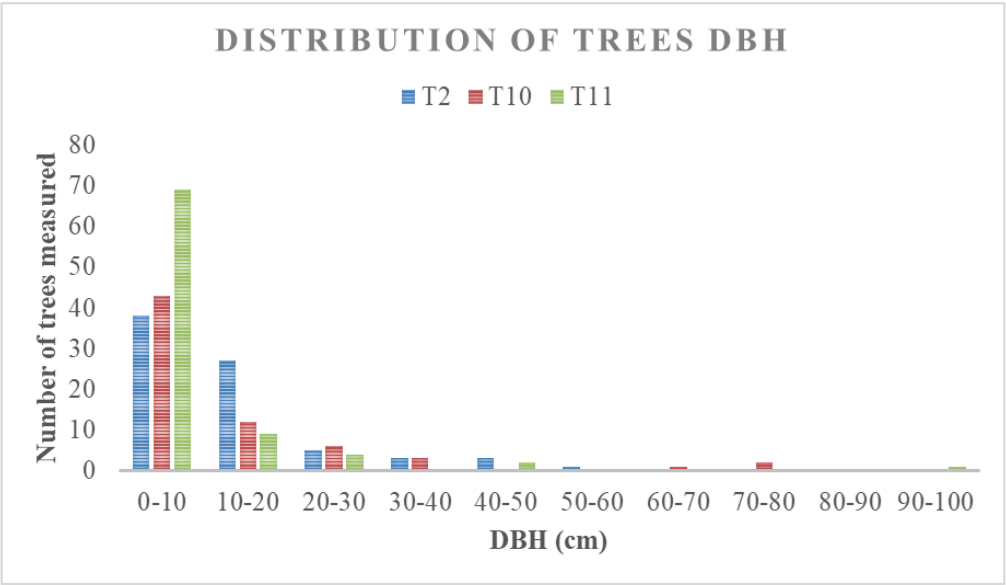


Figure 2. The bar chart demonstrates the distribution of trees with different diameter at breast height in the study area.

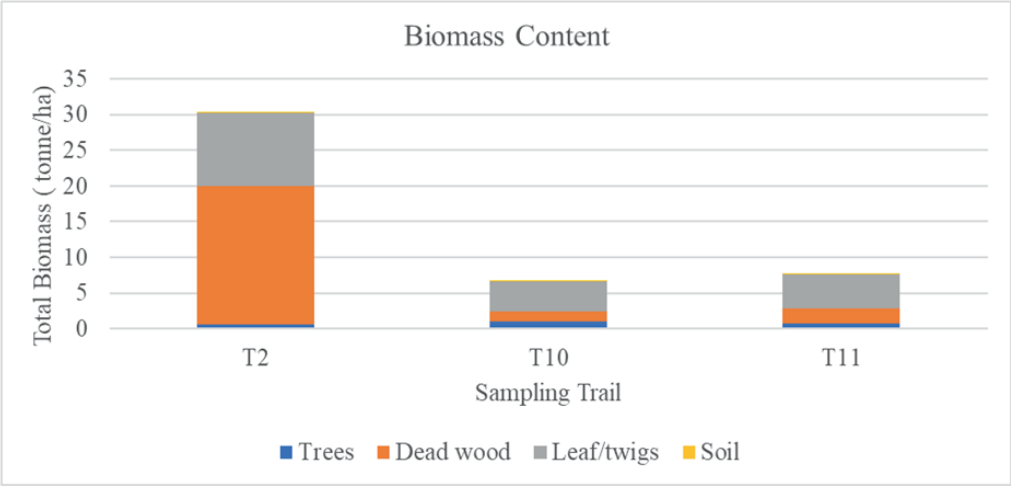


Figure 3. Total biomass for Trail 2, 10 and 11.

Trail 2 had the highest biomass compared to Trail 10 and Trail 11 (Figure 3). If we examined closely, the dead wood and leaf/twigs in Trail 2 were about 20 tonne/ha and 10 tonne/ha respectively.

4 DISCUSSION

The maximum total biomass or AGB found in this study was only 30 Mg ha^{-1}. Other higher findings were reported elsewhere (271±19 to 478±38Mg C ha^{-1}). According to Saatchi et al., (2011), only 7% in Asia, 8.7% in Africa and 7.4% in Latin America have more than 350 Mg ha^{-1} AGB. From T2 results, the dead wood accounted for 60% of the total biomass and the trees biomass is almost negligible. The amount of dead wood is poorly studied and varied across study in tropical forests (less than 10% to more than 40%). According to Komposch et al. (2002), dead wood biomass could vary according to different land uses and elevations. The high dead wood biomass in T2 could be attributed to the previous logging activities.

According to Lee et al. (2015), trees with DBH of less than 10cm are usually disregarded in AGB estimation. This could explain the low tree biomass in this study because 80% of the DBH recorded in this study fell within 0-10cm. The litter dry weight in this study ranged from 5 to 10 Mg ha^{-1}. The result was similar to the one conducted by Moran et al. (2000). Besides dead wood and leaf litter, the biomass of woody plants (≤ 1cm DBH) and herbs was negligible, thus not shown in the result above.

From past studies, root biomass represents 2-25% of the total biomass in various tropical rain forests (Tanaka et al., 2009). This explains the importance of measuring root biomass. However, this component was not studied in this expedition due to time constraints.

5 CONCLUSION

The main carbon pools in the tropical forest ecosystem are the living biomass of trees and understory vegetation and the dead mass of litter, woody debris and soil organic matter (Gibbs et al., 2007). However, due to the past logging activities, the living trees and understory vegetation were low in biomass. Whereas the dead wood and leaf litter were the main contributors of total biomass.

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TREE COMPOSITION IN LOGGED-OVER FOREST IN GERENAI FMU

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Abstract: The study aims to assess the timber group species composition in the logged-over forests of the Gerenai Forest Management Unit (FMU). Logged-over Forest refers to an area of forest that has been subjected to logging activities that have been cut down for commercial purposes such as timber extraction. Logged-over forests play a crucial role in forestry and environmental conservation efforts. Proper management and restoration of logged-over forests are essential to ensure sustainable timber production, biodiversity conservation, and ecosystem health. This aligns with the goals of the Heart of Borneo (HoB) initiative, which emphasizes on the conservation of biodiversity and ecosystems through sustainable forest management. Gerenai FMU covered 148,305 ha and approximately 48% (71,227 ha) of the FMU falls within the HoB corridor. A Permanent Sample Plot was established (20 X 60m) within Coupe 23A. The total number of trees measured was 121 with a diameter at breast height (DBH) of at least 5cm in diameter. The composition of trees within the plot revealed a distribution of 80% non-dipterocarp species and 20% dipterocarp species.

Keywords: logged-over forest, sustainable forest management, Forest Management Unit (FMU), tree composition.

1 INTRODUCTION

Tree composition is the distribution of different tree families, genera, and species within the forest ecosystem. It is important to know the resources of the forest to determine the optimal economic cut in the area. Logged-over Forest is an area of forest that is affected by human disturbance, such as logging activities. The optimal economic cut for logged-over forest refers to the point at which the forest should be harvested to maximize its economic value while also considering ecological sustainability (Lewark, S. (2022).

Overall, the optimal economic cut for logged-over forests involves finding the balance between economic profitability and ecological sustainability, considering both short-term and long-term objectives.

The Heart of Borneo (HoB) conservation agreement is to protect 220,000 km² of forest on Borneo Island. The HoB area in Sarawak covers about 2.1 million ha straddling across Sabah and Sarawak (Malaysia), Brunei, and Kalimantan (Indonesia).

The Forest Department Sarawak is responsible for the management of Permanent Forest and has control over land use especially regulating logging through the issuance of licences or permits for such activities. There are three (3) categories of forests, 1) Permanent Forest consisting of Forest Reserve (FR), which are generally production forest; 2) Protected Forest (PF) which are constituted for the primary purpose of protection of soil and water; and 3) Communal Forest, which are areas used by the community concerned. (section 2, Forest Ordinance 2015)

Based on the data from the Forest Department Sarawak (2019), there are Forest Timber Licenses within the HoB area in Sarawak, with different categories based on land status and activities such as production areas, Forest Timber License (FTL), and Planted Forest (PF), as well as Totally Protected Forest areas (TPAs). The area under Forest Timber Licence (FTL) is 1,499,316 ha and the area under Planted Forest (LPF) is 511,612 ha.

1.1 Background of the study

Sustainable Forest Management (SFM) is a **key component** of the Sarawak Government's **sustainable** development agenda. It requires adherence to principles provided by the Sarawak State Government through the Forest Department and other statutory bodies, such as striking a balance between the dimensions of ecological, economic, and social sustainability, strong support among stakeholders, and ongoing information sharing.

Sarawak has enforced a new policy direction on forest management to manage the forest sustainably. Forest Management Certification is mandatory for all long-term timber licenses in Sarawak. The State's target is to have all the long-term timber licenses to obtain their certification by 2023. (DF Circular No. 1/2021 dated 14.04.2021)

For all certified Forest Management Units (FMU), the harvesting cutting limit of trees at breast height (DBH) is **≥45cm** for non-dipterocarp species and **≥50cm** for Dipterocarp species. (The Green Book, Manuals, procedures, and guidelines for Forest Management Certification in Sarawak Natural Forest, 2015).

The need for Sustainable Forest Management (SFM) has since been reflected in the statement of the Forest Policy of Sarawak, where the sustainability of the forest, and safeguarding of the environment and local communities were very much emphasized.

Forest Management Certification (FMC) is a tool to drive Sustainable Forest Management. It is confirmation of compliance of Forest Management practices with an agreed set of rules "expended in the form of principles, criteria, indicators & Management Specification (verifiers).

2. Objectives of the study

There are limited inventory studies on logged-over forests to determine the effectiveness of the current cutting girth limit policy. Currently, the harvesting cycle is 25 years, following the forest certification standard (Samejima et al., 2020).

i. Tree composition based on family group.

ii. Size class/average diameter of tree at logged-over forest.

iii. Average high of tree at logged-over forest.

1 MATERIALS AND METHODS

2.1 Study site

The study was conducted at Gerenai Forest Management Unit (FMU). Gerenai FMU which was the first FMU to be certified in Miri Division in April 2020. The FMU has a gross area of about 146,242 ha and is located between Latitude 2° 40' N to 3° 15' N and Longitude 114° 34 E to 115° 16' E in Miri Division, Sarawak. The Gerenai FMU is licensed under Forest Timber License T0413 to Samling Plywood (Miri) Sdn. Bhd., as shown in Figure 1.

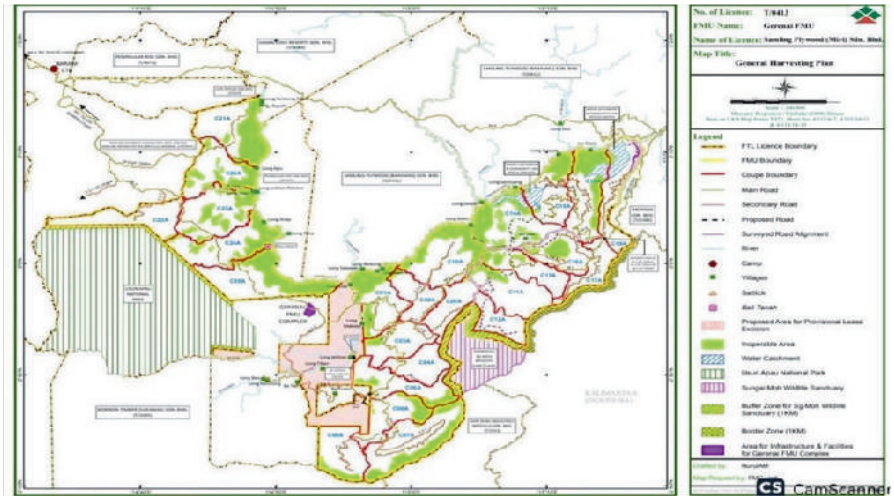


Figure 1: Location of the plot used in the study within coupe 25A Gerenai FMU

2. Establishment of permanent sample plot (PSP)

The plot establishment after the completion of all logging operations, a 20m X 60m (0.12 ha), layout of the PSP is shown in Figure 2. Coordinates, elevation, and bearing for the plot are shown in Table 1 and 2.

Each Permanent Sample Plot (PSP) comprises 10m X 10m subplots. Within each plot, tree enumeration encompasses all trees (excluding Macaranga sp.) with a diameter at breast height (DBH) of 5cm or larger. Trees with a DBH of 10 cm and above are individually tagged with metal tags and recorded for pertinent details as follows:

iv. Species.

v. Diameter at breast height.

vi. Height at first branching

All diameter measurements were taken at breast height (1.3 m) or in the case of buttressed trees, 0.3 m above the buttress.

Table 1: GPS coordinates and elevation above sea level for each point in Plot

Point Name	GPS Coordinate (Timbalai 1948)	Elevation (m a.s.l.)
Point A	N2° 58' 39.26", E114° 48' 3.35"	588m
Point B	N2° 58' 36.30", E114° 48' 4.71"	587m
Point C	N2° 58' 37.88", E114° 48, 1.76"	565m
Point D	N2° 58' 37.88", E114° 48' 0.41"	574m
Tie Point	N2° 58' 38.68", E 114° 48' 4.17"	

Table 2: Bearing of PSP plot.

Direction	Bearing
A ⮉ B	155°
B ⮉ C	245°

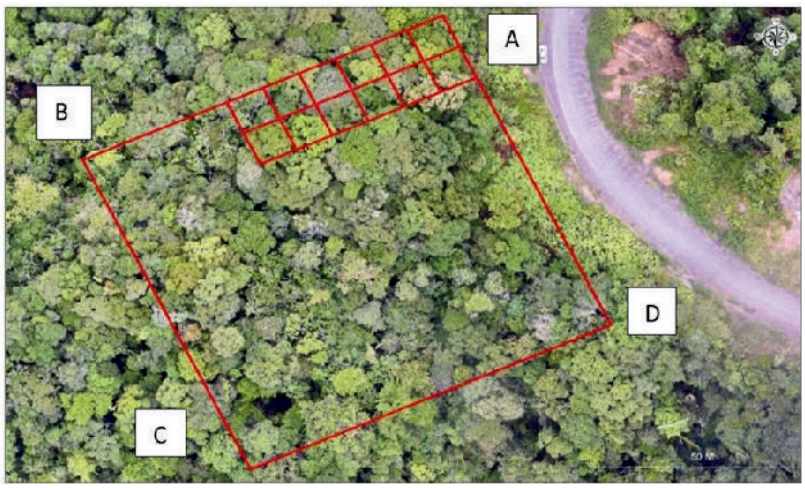


Figure 2: Ortho mosaic processed from drone overlayed with plot, quadrant, and sub-quadrant

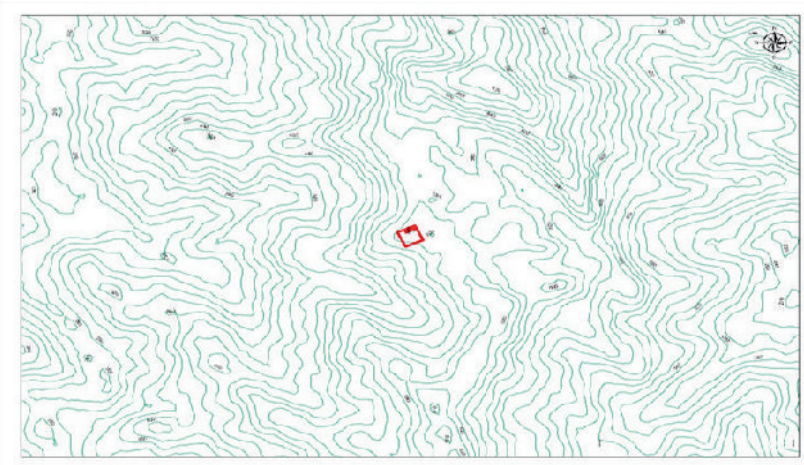


Figure 3: Digital elevation model of selected site using data derived from Shuttle Radar Topography Mission (SRTM) 30 meters

2.3 Plot inventory

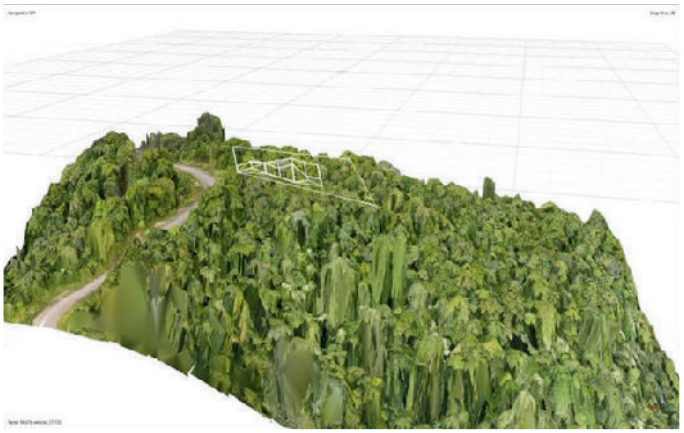


Figure 4: 3D surface modal rendered from drone images

One (1) plot in selectively logged forest in 2014 within HoB area. All commercial timber group stems ≥5 cm DBH (at 1.3 m or immediately above buttresses if higher) were recorded. The tree class was then further divided into 5-14.9 cm, 15-29.9 cm, 30-44.9 cm, 45-49.9 cm, 50-59.9 cm, and ≥60 cm DBH subsets. Each stem was identified using leaf specimens, based on collections available at the Forest Department Herbarium and in collaboration with botanical experts during the HoB expedition. All dipterocarps were identified to genus level (Table 3).

2.4 Data analyses

Table 3: Number of Trees by Family

No.	Family Name	Total No. of Trees
1	Myrtaceae	26
2	Dipterocarpaceae	25
3	Lauraceae	22
4	Anacardiaceae	15
5	Fagaceae	15
6	Apocynaceae	3

7	Burseraceae	3
8	Dilleniaceae	3
9	Myristicaceae	3
10	Ebenaceae	2
11	Sapotaceae	2
12	Malvaceae	1
13	Polygalaceae	1
	Total	121

Table 4: Distribution by Species Group

Species Group	**No. of trees**	**Percentage**
Dipterocarp	25	20%
Non-diptrocarp	96	80%
Total	121	

Table 5: Distribution by diameter class

SPECIES GROUP	DIAMETER CLASS (cm)/no.of tree (pcs)						
	5.0-14.9	15.0-29.9	30.0-44.9	45.0-49.9	50.0-59.9	60.0+	TOTAL
Dipterocarp	12	7	3	1	1	1	23

Non-dipterocarp	46	33	12	2	2	1	96
TOTAL	58	40	15	3	3	2	121

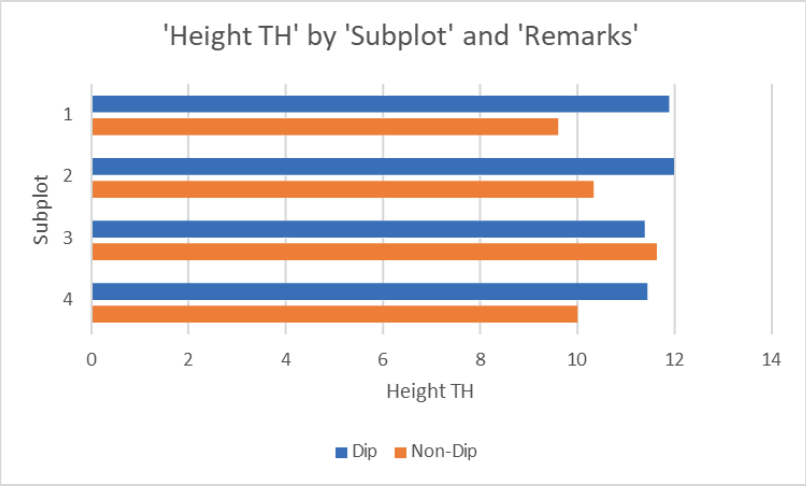


Figure 6: Total height (at first branch) of the tree in meter

3 RESULTS

In total, 121 trees with 5 cm DBH and larger were recorded from the plot. Tables 3 & 4 show the frequency of trees by species timber group. Table 5 shows the frequency and their proportional distribution respectively, of trees 5 cm DBH and larger. Figure 6 shows the frequency for the tree height based on the species timber group.

The total number of trees with DBH 45 cm and larger was 8 trees while there were 23 trees which were dipterocarps in the plot. The sample size was too small so the result does not present the Gerenai FMU composition as a whole. More study plots must be established for this purpose. Enrichment planting in logged-over forests is a beneficial initiative to address the reduced diversity in the graded area.

4 CONCLUSION

A total of 121 trees were recorded in the PSP Plot, with non-Dipterocarpaceae emerging as the dominant tree family, constituting approximately 80% of the recorded trees. The average DBH within the plot was measured at 19.8cm. To sustainably manage the forest and facilitate certification in Sarawak, a 25-year harvesting cycle has been established for the FMU. Furthermore, post-logging enrichment planting initiatives have been implemented as mandatory measures aimed at aiding the regeneration of logged-over areas.

ACKNOWLEDGMENT:

We would like to express our gratitude to the Forest Department Sarawak and Universiti Putra Malaysia (Bintulu Campus) for their invaluable support and guidance throughout the research project. Special thanks also to Regional Forest Officer, Miri Regional Office for the support and also to the Heart of Borneo team for the tremendous effort in organising the scientific expedition. We acknowledge the assistance from the Long Mekabar community and Gerenai FMU to ensure the ground activities are carried out smoothly. Lastly, we would like to extend our appreciation to the State Government for the financial support through the Projek Rakyat.

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Day 2
13th October 2023

HEART OF BORNEO SCIENTIFIC EXPEDITION TO LONG MEKABA – GERENAI FMU: A REPORT ON FLORA DIVERSITY

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Abstract: This paper presents a summary report on the flora diversity of Long Mekaba - Gerenai FMU based on the collaborative work of five flora teams from the Forest Department Sarawak, Forest Research Institute Malaysia, Sabah Forestry Department, University of Malaysia Sarawak (UNIMAS), and University of Brunei Darussalam during the expedition from 12 to 25 September 2023. Surveys were conducted along the transects established prior to the expedition and at the surrounding areas. These areas consist of logged-over and disturbed mixed dipterocarp forests, including riparian forest at elevations between 140–582 m a.s.l. The species recorded were based on collections of fertile plants collected following the standard herbarium collection method as well as the collection of sterile specimens from the temporary sample plots established during the expedition. Over 1,000 herbarium and voucher specimens were collected during this expedition, representing over 600 species from 217 genera and 102 families of flowering plants, ferns and lycophytes. The collections comprise some endemic, rare, and threatened species. Prior to this expedition, there was no information on the flora from Long Mekaba and Gerenai FMU. Therefore, the flora surveys carried out during the expedition provide the baseline information about the flora diversity of the area, and the collected herbarium specimens become valuable reference materials for future research. The information on the flora species within the expedition area is important for recommending appropriate management measures for the sustainable management and conservation of rare, threatened, and endangered plant species in the Heart of Borneo and adjacent forests.

Keywords: conservation, endemic plants, mixed dipterocarp forest, rare

1 INTRODUCTION

A Scientific Expedition known as Long Mekaba-Gerenai FMU organised under the Heart of Borneo (HoB) Sarawak was conducted at Long Mekaba from 12 to 25 September 2022. Long Mekaba is within the Gerenai Forest Management Unit (FMU), situated at Batang Baram - Sungai Silat, in Miri Division in the North-Eastern part of Sarawak. The Gerenai FMU shared boundaries with Usun Apau National Park at the eastern part and Sungai Moh Wildlife Sanctuary at the north-eastern part (Figure 1). The FMU mainly comprises of lowland to hill mixed dipterocarp forests with elevation ranges from 150 m to over 1,800 m a.s.l. The major rivers flow through the FMU are from tributaries of Sg. Baram, namely Sg. Silat and Sg. Moh. Riparian vegetation can be found along the rivers.

Forests within the HoB are known as hyper diverse area with high endemicity in terms of flora and fauna (Ashton, 2010). Prior to this expedition, there is little to no information on the flora from Long Mekaba-Gerenai FMU. Hence, one of the objectives is to document the rich flora from the expedition area. The report on flora diversity of Long Mekaba - Gerenai FMU presented in this paper is based on the collaborative work of five flora teams from the Forest Department Sarawak (FDS), Forest Research Institute Malaysia (FRIM), Sabah Forestry Department (SFD), University of Malaysia, Sarawak (UNIMAS) and University of Brunei Darussalam (UBD).

2 METHODOLOGY

The survey works were mainly conducted along the transects established for the expedition as well as forest areas adjacent to the transects. The transects vary between 2–4 km long, cutting through forests and streams. A collection of plants was made following the standard herbarium collection method (Bridson & Forman, 1992). At least one duplicate of each collected specimen is kept at Sarawak Herbarium (SAR). For small plants and fragile flowers, the spirit collection method was applied. Preservation of spirit material was made using Copenhagen Solution (70% ethanol, 28% distilled water and 2% glycerol). In addition to the collection of herbarium specimens, voucher specimens of trees from the temporary plots were also collected by the team from UBD.

Identification of the specimens were done based on published papers/journals/books and collaborative work with experts. The latest accepted names used in the paper are following those in the Plant of the World Online (POWO, 2023). The conservation status of the species is based on IUCN Red List of Threatened Species (IUCN, 2023).

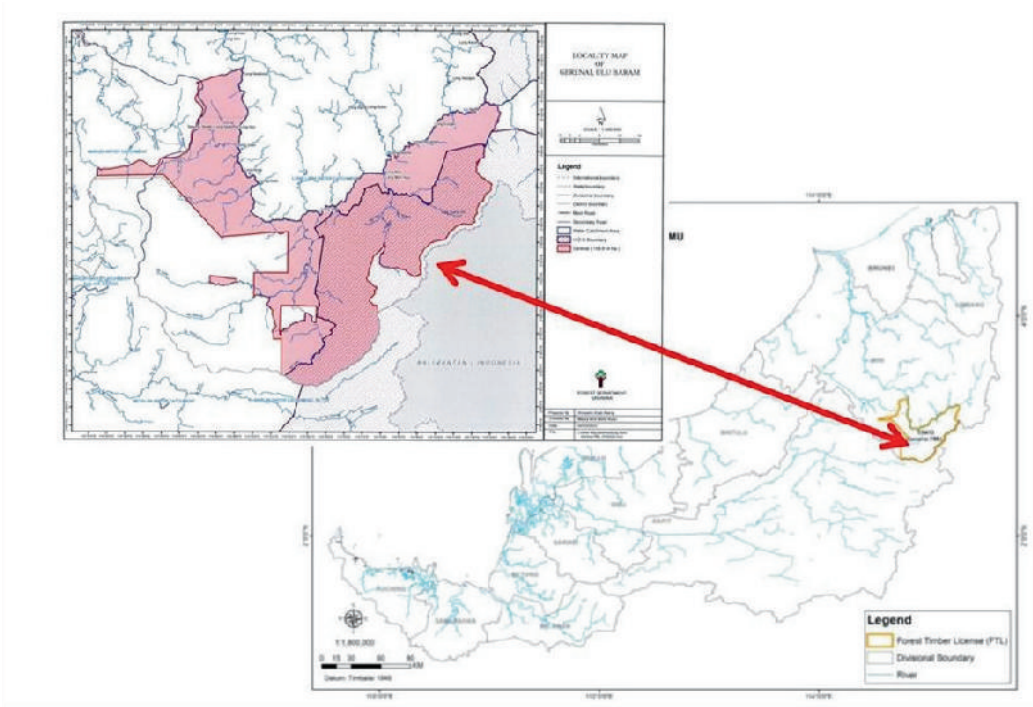


Figure 1: The locality of Gerenai FMU and expedition site.

2.1 Collection sites

During the expedition, the collection of specimens was carried out along the transects established prior to the expedition and in the adjacent forests. Figure 2 shows the collection sites visited by the team members. The collections were done mainly from the water catchment of Long Mekaba (outside of the HoB boundary), and within the HoB boundary in the logged-over forests. The forests within the water catchment area are relatively still intact; however, most of the collection sites within the HoB boundary consist of logged-over forest with wide canopy gaps. Intact forest within the HoB boundary can be found within the buffer zone along the rivers and streams. Most of the collections were targeting sites along the small rivers and streams with relatively good forests.

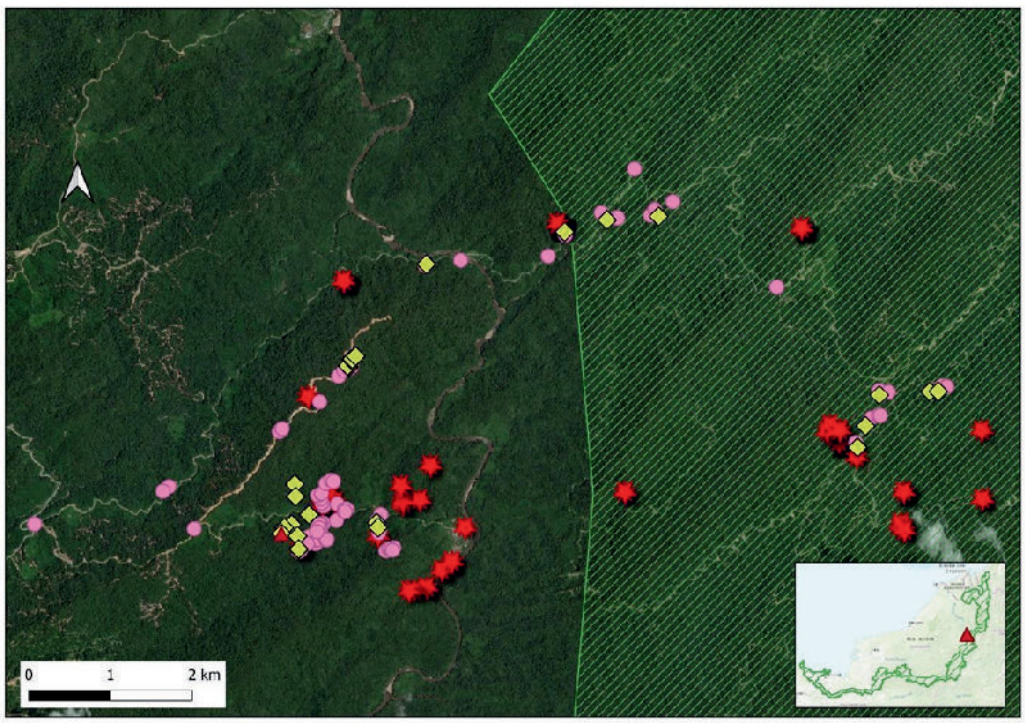


Figure 2: The collection sites by flora teams during the Expedition

3 FINDINGS

Over 1,000 specimens and vouchers were collected during the expedition representing over 600 species from 217 genera and 102 families. The most common families recorded are Rubiaceae with 143 collections, followed by Genesriaceae and Zingiberaceae (Table 1). The most common genera recorded are *Cyrtandra,* followed by *Selaginella* and *Argostemma* (Table 2). At the time of this publication, a total of 462 species (including subspecies) have been identified. The collections represent 40% herbaceous plants, 26% trees and the remaining percentage include shrubs, climbers and mycoheterotrophic plants. Out of 462 species identified, nine (9) species are endemic to Sarawak (Table 3). Three species documented are new records for Sarawak. A total of 11 species is categorised as threatened based on the conservation status of the species listed in the IUCN Red List of Threatened Species (IUCN, 2023) (Table 4).

Table 1: Five most common family recorded

No.	Family	Number of collections
1	Rubiaceae	143
2	Gesneriaceae	97
3	Zingiberaceae	95
4	Melastomataceae	69
5	Selaginellaceae	26

Table 2: Five most common genera recorded

No.	Family	Number of collections
1	*Cyrtandra*	75
2	*Selaginella*	26
3	*Argostemma*	25
4	*Acranthera*	21
5	*Begonia*	20

Table 3: Species endemic to Sarawak

Family	Species
Gesneriaceae	*Cyrtandra dorytricha* Hilliard & B.L.Burtt
Gesneriaceae	*Cyrtandra scutifolia* B.L.Burtt
Melastomataceae	*Driessenia sessiliflora* C.Hansen
Cyperaceae	*Mapania ballehensis* Miraadila, Shabdin & Meekiong
Musaceae	*Musa campestris* var. *lawasensis* Häkkinen
Costaceae	*Paracostus* (*Costus*) *muluensis* Meekiong, Ipor & Tawan
Selaginellaceae	*Selaginella chaii* Jermy
	Chuselaginella sarawakensis (Hieron.) Li Bing Zhang & X.M. Zhou
	Hypopterygiopsis chaii (Jermy) Li Bing Zhang & X.M. Zhou

Table 4: Threatened species recorded from Long Mekaba-Gerenai FMU

No.	Family	Species	Conservation status
1	Zingiberaceae	*Boesenbergia stenophylla* R.M.Sm.	CR
2	Zingiberaceae	*Etlingera burttii* A.D.Poulsen	EN
3	Zingiberaceae	*Plagiostachys brevicalcarata* Julius & A.Takano	EN
4	Zingiberaceae	*P. crocydocalyx* (K.Schum.) B.L.Burtt & R.M Sm	EN

5	Zingiberaceae	*Alpinia ligulata* K.Schum.	VU
6	Lauraceae	*Eusideroxylon zwageri* Teijsm. & Binn.	VU
7	Myristicaceae	*Horsfieldia fragillima* Airy Shaw	VU
8	Myristicaceae	*Knema subhirtella* W.J.de Wilde	VU
9	Zingiberaceae	*Zingiber longipedunculatum* Ridl.	VU
10	Zingiberaceae	*Zingiber pachysiphon* B.L.Burtt & R.M.Sm.	VU
11	Zingiberaceae	*Zingiber pseudopungens* R.M.Sm.	VU

Note: Critically Endangered (CR), Endangered (EN), Vulnerable (VU)

Some noteworthy discoveries:

Family Rubiaceae is one of the most common and abundant plants collected at Long Mekaba-Gerenai FMU. A total of 59 species from 28 genera were recorded. Some of the interesting species are the Bornean endemic species such as *Argostemma. hameliifolium* Wernham, *A. havilandii* Ridl., *A. moultonii* Ridl. and *A. rupestre* Ridl., *Stichianthus minutiflorus* Valeton, and *Ophiorrhiza fibrillosa* Ridl.

The Genesneriaceae is another commonly recorded family, with 32 species from 4 genera. The genus *Cyrtandra* is the most abundant group with approximately 24 species of which 20 species are endemic to Borneo, including two (2) species that are endemic to Sarawak. Among the species in genus *Cyrtandra*, *Cyrtandra basiflora* C.B.Clarke is one of the most common species recorded. This species is mainly found along the creeks and streams. *Cyrtandra scutifolia* B.L.Burtt is endemic to Sarawak. The species was previously recorded from two other localities and Long Mekaba-Gerenai FMU is the third locality of the species in Sarawak.

The species from the family Melastomataceae are also considered common family documented from the expedition sites. A total of 26 species from 14 genera were recorded. Of these, 18 species are endemic to Borneo including one (1) species (*Driessenia sessiliflora* C.Hansen) endemic to Sarawak. *Driessenia sessiliflora* is also considered rare and only recorded from two different transects from the expedition sites. Meanwhile, *Melastoma joffrei* K.M.Wong & Y.W.Low, a Bornean endemic species, is also considered rare and only recorded from one transect at Long Mekaba-Gerenai FMU.

A total of seven species of *Begonia* were recorded from Long Mekaba-Gerenai FMU. The diversity of *Begonia* species in Long Mekaba-Gerenai FMU is like other HoB expedition sites such as Long Banga and Tama Abu PF.

Another interesting finding during the expedition is the discovery of 12 species of mycoheterotrophic plants (Polygalaceae – 4 species, Orchidaceae – 4 species, Burmanniaceae – 2 species, Thismiaceae – 2 species, Triuridaceae – 2 species). Of these, 3 species are endemic to Borneo and 1 new record (*Thismia pallida*).

4 DISCUSSION

This report is based on collective information from the survey done by five flora teams resulting in the documentation of over 600 species from 217 genera and 102 families. The collative efforts and collaborations from the flora teams are important to produce a more comprehensive report on the diversity of flora from the expedition sites. During the expedition, most of the teams collected understorey plants (e.g., small trees, herbaceous plants), with only one team focused on documenting tree species in the temporary plots. This approach leads to biases in the collections. As such, the actual diversity of tree species from the expedition sites is most probably underestimated, as most of the trees encountered were either sterile or too tall to be sampled.

The presence of rare, threatened, and endemic (RTE) species from the expedition sites indicates that although the forests have been logged in the past, the forests still harbour a good representative of forest species and important for the conservation of RTE species. The presence of indicator species such as the mycoheterotrophic plants also indicate that the forest conditions within the collection sites are still in good condition as this group of plants required forests with good condition to flourish (Dancak et al., 2020; Merckx et al., 2009). The concentration of RTE species is also important in identifying Key Biodiversity Areas (KBA). The expedition sites were located in between KBA sites and HoB sites (Figure 3). This forms an important corridor not only for wildlife but also for seed dispersal and distributions of flora within and adjacent to KBA and HoB sites (Ashton, 2010).

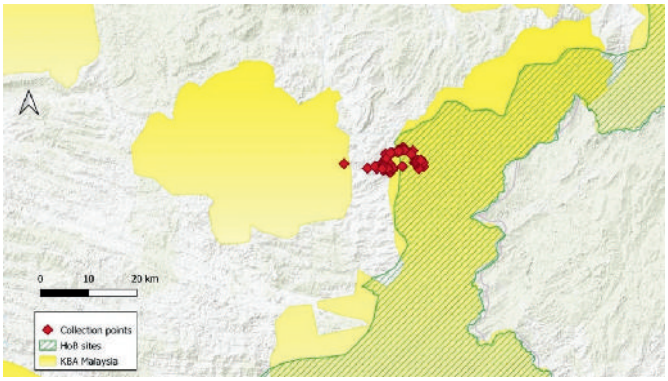


Figure 3: Collection sites situated in between KBA and HoB site

5 CONCLUSION

The HoB Initiatives is important to enhance conservation efforts for more sustainable and responsible forest management to conserve the diversity of flora and fauna, as well as to safeguard the environmental and social aspects of the areas within the HoB sites. Heart of Borneo expeditions provide baseline information on flora diversity of the area and herbarium specimens become valuable reference material for future research. The information on the conservation status of flora species from the expedition area is important for recommending appropriate management measures for the sustainable management and conservation of rare, threatened, and endangered plant species in the Heart of Borneo and adjacent forests.

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FERNS AND LYCOPHYTES OF LONG MEKABA, GERENAI, NORTH-EASTERN SARAWAK

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Abstract: A 12 days botanical survey for ferns and lycophytes study was carried out between 13th to 24th September 2022 during the Heart of Borneo (HoB) Scientific Expedition in Long Mekaba-Gerenai FMU, Ulu Baram Miri, Sarawak. A random collection of ferns and lycophytes was carried out where fertile specimens were collected along the existing trails and surrounding areas. Some species which are common or still in a sterile stage were observed and recorded but not collected. As a result, 23 families were identified, comprising 60 genera with 135 species and infraspecific taxa. Among the findings, 18 species are endemic to Borneo, including two (2) Selaginellaceae that are hyper-endemic to Sarawak, viz *Chuselaginella sarawakensis* and *Hypopterygiopsis chaii*, where the later also listed among the rare and threatened pteridophytes of Asia. Among the species collected, *Didiclis padangensis* (Selaginellaceae), *Diplazium porphyrorachis* (Athyriaceae), *Hymenophyllum cardunculus* (Hymneophyllaceae), and both *Mesophlebion beccarianum* and *Pronephrium hosei* (Thelypteridaceae) are restricted species, so far only reported from two to three islands including Borneo. Some specimens are suspected to be new records for Sarawak and Borneo, yet to be confirmed pending for further investigation; hence,the species identification status remains unknown in this paper. Despite a low number of taxa, this discovery significantly contributes to botanical knowledge and understanding of Sarawak's ferns and lycophytes. Furthermore, discovering of Bornean endemics is particularly important, as these species are often confined to specific habitats with a restricted distribution range. Such findings provide valuable insights into the biodiversity and ecological significance of the studied area. The findings such as these strongly justified the decision to demarcate Gerenai-Long Mekaba as a conservation area under the Heart of Borneo project. Overall, this botanical survey has successfully expanded our knowledge of ferns and lycophytes in the Heart of Borneo, particularly the north-eastern part of Sarawak. This information will undoubtedly be helpful for further research, conservation initiatives, and understanding of the distinctive flora of Sarawak.

Keywords: Borneo, endemic, diversity, flora, pteridophyte

1 .INTRODUCTION

The Long Mekaba is part of the Gerenai Forest Management Unit (FMU), situated at Batang Baram - Sungai Silat, in Miri Division, North-Eastern Sarawak, Malaysian Borneo (Figure 1). The FMU mainly comprises of lowland to hill mixed dipterocarp forests with elevation ranges from 150 m to 1800 m a.s.l. The major rivers flow through the FMU are from tributaries of Sg. Baram, namely Sungai Silat and Sungai Moh. Riparian vegetation also can be found along the rivers.

Long Mekaba-Gerenai Scientific Expedition was conducted under the 9th Heart of Borneo (HoB) Sarawak from 12th to 25th of September 2022. The aim was to explore the hinterland of the North-Eastern Sarawak within the Long Mekaba, Gerenai FMU, Ulu Baram Miri, Sarawak. The main objectives of this expedition are to document the richness of flora and fauna of the areas. For our group, we were focusing on the diversity of ferns and lycophytes of the study area.

The aim of this study is to come up with a checklist of ferns and lycophytes from the Long Mekaba-Gerenai FMU and to identify the high conservation value species for further protection and conservation by the FMU and to create awareness for local communities in conservation of biodiversity specifically.

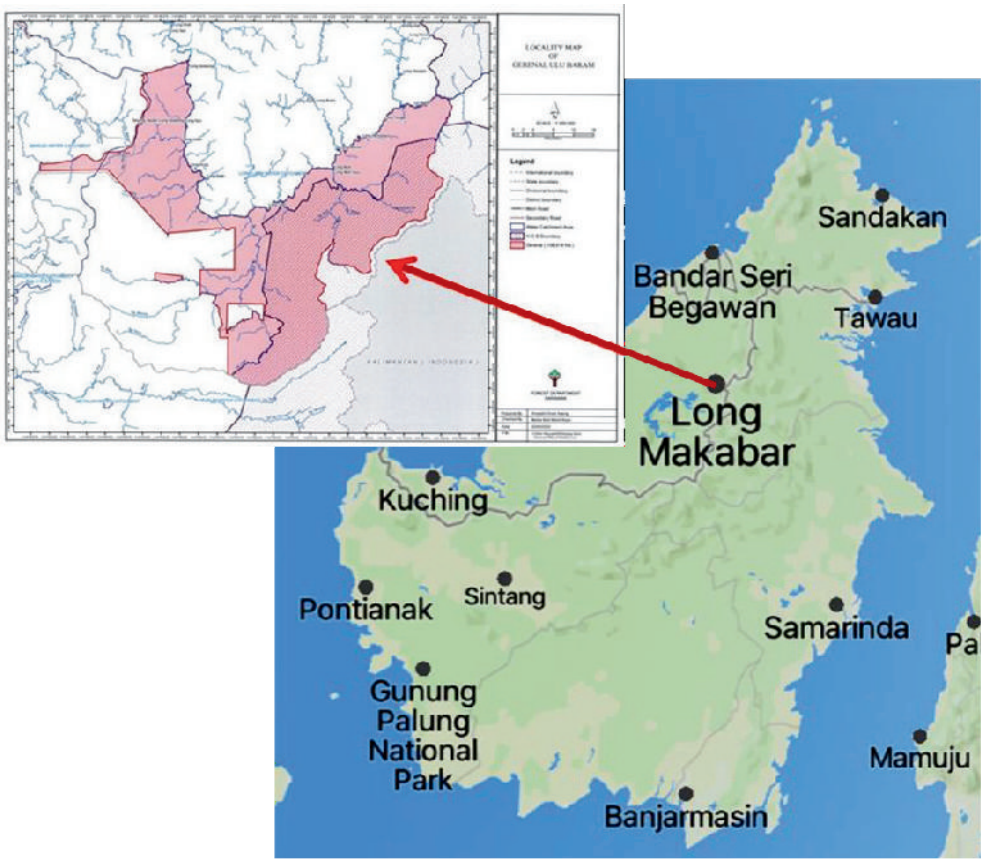


Figure 1. The location of the Long Mekaba-Gerenai FMU.

The ferns and lycophytes flora of Borneo is rich both in numbers of species and in their importance in the vegetation. It is suspected more than 1,000 species occur within the Bornean region, and if Sabah with relatively smaller land cover recorded 900 species and 26 infraspecific taxa of ferns and lycophytes (Andi et al., 2022), we believed Sarawak has more or at least similar number of species. Previously, several studies conducted on ferns and lycophytes of Sarawak includes studies by Jermy (1983), Parris et al. (1984); Parris & Latif (1997) and Chen et al. (2021). The preliminary finding of this study was presented during the Sarawak HOB Seminar: Long Mekaba-Gerenai by Andi et al. (2023).

2 METHODOLOGY

The Sarawak HOB Scientific Expedition to Long Mekaba-Gerenai FMU was organized by the Forest Department Sarawak from 12th to 25th September, 2022. During the expedition, a

botanical survey for ferns and lycophytes was carried out between 13th to 24th September 2022 in the Long Mekaba-Gerenai FMU. A random collection of ferns and lycophytes was carried out where mature/fertile specimens were collected along the trails and surrounding areas. Some species which are common or sterile were observed and recorded, but not collected. These common species were identified to the species level in the field based on their distinctive field characteristics. Specimens collected were recorded in databases, pressed and dried with portable dryer in the campsite. After reaching the herbarium, pressed specimens were dried using electric oven at 55°C for several days before proceeding with the identification process.

All specimens were sorted according to morphospecies and attempted for identification to species level by cross-referencing with the existing specimens in the herbaria (SAN, SAR, FRIM) and related flora references (e.g., Andi et al., 2022; Beaman & Edwards, 2007; Chao et al., 2014; Chen et al., 2017, 2021, 2022; Holttum, 1987, 1991; Parris et al., 1984, 1992; Rothfels et al. 2012; and etc.). Records of species from the BRAHMS database system (BRAHMS-SAN, 2023) were also incorporated with the current study.

We followed the classification of Christenhusz et al. (2011) and PPG I (2016) with additional modifications based on the World Flora Online (WFO, 2024), and COL Checklist (Bánki et al., 2024). Herbarium abbreviations follow Thiers (2021). In terms of occurrences, distributions, and endemism status of each taxon, other than information from the specimens cited, we also referred and synchronised the specimen information with the BRAHMS-SAN (2023), GBIF.org (2024), PCC (2024), and Andi et al. (2022). The conservation status of the species is based on IUCN (2024).

3 RESULTS AND DISCUSSION

A total of 135 species and infraspecific taxa were identified from the Long Mekaba-Gerenai FMU (Appendix 1). These are represented by two (2) lycophytes and 21 fern families, with seven (7) and 53 genera, respectively (Table 1). Some of the pictures from the collections are depicted in Appendix 2 (Figures 2-3). The IUCN Red List Categories and Criteria which were designed for global taxon assessments show that only 2% of lycophytes and ferns have been assessed globally. Most of the species identified from the study area have not been evaluated, except for the two ferns species which were evaluated as Least Concern (LC).

Table 1. Summary of the number of ferns and lycophytes recorded from Long Mekaba-Gerenai FMU.

Group	Family	No. of Genera	No. of Species and infraspecific taxa
Lycophytes	Lycopodiaceae	2	4
	Selaginellaceae	5	21
Ferns	Aspleniaceae	1	4
	Athyriaceae	2	9
	Blechnaceae	1	2
	Cyatheaceae	3	6
	Davalliaceae	1	3
	Dennstaedtiaceae	1	1
	Dipteridaceae	1	2
	Dryopteridaceae	3	4
	Gleicheniaceae	2	2
	Hymenophyllaceae	4	10
	Lindsaeaceae	1	9
	Lomariopsidaceae	1	1
	Lygodiaceae	1	1
	Marattiaceae	2	2
	Nephrolepidaceae	1	1
	Oleandraceae	1	1
	Polypodiaceae	10	16
	Pteridaceae	6	10
	Schizaeaceae	2	4
	Tectariaceae	3	9
	Thelypteridaceae	7	13
	SUM	**60**	**135**

Of the 135 species and infra-specific taxa identified, 18 species are endemic to Borneo including six ferns, i.e., *Diplazium vestitum* var. *borneense* (Athyriaceae), *Gymnosphaera ramispina* (Cyatheaceae), *Polydictyum ternatum* (Tectariaceae), *Tectaria inopinata* (Tectariaceae), *Pronephrium firmulum* (Thelypteridaceae) and *Sphaerostephanos pterosporus* var. *crenatus* (Thelypteridaceae). Twelfth (12) out of 18 Borneo's endemics recorded are from a single family, Selaginellaceae (Appendix 1).

Selaginellaceae is a monotypic genus Sellaginella with more than 700 species worldwide. It is considered the largest and most taxonomically complex genus in lycophytes. For this paper, we followed the classification of Selaginellaceae based on a recent phylogeny study by Zhou and Zhang (2024); however, the placement of some species in this family remains uncertain (where its broader relationships are unknown or still undefined) for further clarification and more study needed in the near future.

Interestingly, another two (2) Selaginellaceae are hyper-endemic to Sarawak, viz *Chuselaginella sarawakensis* and *Hypopterygiopsis chaii*, where the later is also listed in the rare and threatened pteridophytes of Asia (Ebihara et al., 2012). Among the species collected, *Didiclis padangensis* (Selaginellaceae), *Diplazium porphyrorachis* (Athyriaceae), *Hymenophyllum cardunculus* (Hymneophyllaceae), and both *Mesophlebion beccarianum* and *Pronephrium hosei* (Thelypteridaceae) are restricted species, so far only reported from two to three islands including Borneo (Appendix 1). Some specimens are suspected to be new records for Sarawak and Borneo, but yet to be confirmed after further investigation; hence, the species identification status remain unknown i.e., listed as sp. in this paper.

Based on the collections during this expedition, the biggest family is Selaginellaceae with 21 taxa, followed by Polypodiaceae with 16 taxa and Thelypteridaceae with 13 taxa. In terms of legal protection, all Cyatheaceae is listed as protected species in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and Sabah Wildlife Conservation Enactment 1997 (Part II: Section 54 (1)(b) Protected Plants). A total of six (6) Cyatheaceae species were recorded during this survey.

4 CONCLUSION

The surveys recorded 135 species and infra-specific taxa from the Long Mekaba-Gerenai FMU, of which 18 species are endemic to Borneo, including two (2) species that are considered hyper-endemic to Sarawak. The forests in Long Mekaba-Gerenai FMU contain high conservation value plant species. Despite the low number of taxa recorded as compared to Gunung Mulu National Park, Sarawak, and Mt. Kinabalu in Sabah, the findings of this study show that the Long Mekaba-Gerenai FMU is an important habitat for rare and endemic ferns and lycophytes in Borneo.

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APPENDICES:

APPENDIX 1. List of ferns and lycophytes species recorded from the Long Mekaba-Gerenai FMU. The species are arranged by family in alphabetical order, and follows Christenhusz et al. (2011) and PPG I (2016) with additional modifications based on World Flora Online (WFO, 2024), and COL Checklist (Bánki et al., 2024) websites.

Symbols indicated as below: -
Species endemic to Borneo
Species endemic to Sarawak
^ Restricted distribution

A. LYCOPHYTES

1. LYCOPODIACEAE

1. *Palhinhaea*
   - *Palhinhaea cernua* (L.) Vasc. & Franco
2. *Phlegmariurus*
   - *Phlegmariurus nummulariifolius* (Blume) Ching
   - *Phlegmariurus phlegmaria* (L.) Holub (Fig.2a)
   - *Phlegmariurus squarrosus* (G. Forst) Löve & Löve (Figure 2b)

2. SELAGINELLACEAE

1. *Chuselaginella*
   - *Chuselaginella alopecuroides* (Baker) Li Bing Zhang & X.M. Zhou #
   - *Chuselaginella brooksii* (Hieron.) Li Bing Zhang & X.M. Zhou #
   - *Chuselaginella cupressina* (Willd.) Li Bing Zhang & X.M. Zhou
   - *Chuselaginella dielsii* (Hieron.) Li Bing Zhang & X.M. Zhou #
   - *Chuselaginella grandis* (T. Moore) Li Bing Zhang & X.M. Zhou #(Fig.2c)
   - *Chuselaginella intermedia* (Blume) Li Bing Zhang & X.M. Zhou
   - *Chuselaginella longiaristata* (Hieron.) Li Bing Zhang & X.M. Zhou
   - *Chuselaginella paxii* (Hieron.) Li Bing Zhang & X.M. Zhou #
   - *Chuselaginella sarawakensis* (Hieron.) Li Bing Zhang & X.M. Zhou ##
   - *Chuselaginella* sp.

Chuselaginella subcalcarata (Alderw.) Li Bing Zhang & X.M. Zhou #

2. *Didiclis*
   - *Didiclis conferta* (T. Moore) Li Bing Zhang & X.M. Zhou #
   - *Didiclis hewittii* (Hieron.) Li Bing Zhang & X.M. Zhou #
   - *Didiclis lobbii* (Veitch ex A. Braun) Li Bing Zhang & X.M. Zhou #
   - *Didiclis padangensis* (Hieron.) Li Bing Zhang & X.M. Zhou ^
     Restricted distributions: Borneo, Peninsular Malaysia, Sumatra
   - *Didiclis wallichii* (Hook. & Grev.) Li Bing Zhang & X.M. Zhou
   - *Didiclis* sp.
3. *Hypopterygiopsis*
   - *Hypopterygiopsis boninensis* (Baker) Li Bing Zhang & X.M. Zhou
   - *Hypopterygiopsis chaii* (Jermy) Li Bing Zhang & X.M. Zhou ##Mulu NP
4. *Kungiselaginella*
   - *Kungiselaginella involvens* (Sw.) Li Bing Zhang & X.M. Zhou
5. *Selaginella*
   - *Selaginella boschai* #Incertae sedis

B. FERNS

3. ASPLENIACEAE

1. *Asplenium*
   - *Asplenium affine* Sw.
   - *Asplenium batuense* Alderw.
   - *Asplenium nidus* L.
   - *Asplenium tenerum* G. Forst.

4. ATHYRIACEAE

1. *Diplazium*
   - *Diplazium bantamense* Blume
   - *Diplazium cordifolium* Blume
   - *Diplazium cumingii* (C. Presl) C. Chr.
   - *Diplazium esculentum* (Retz.) Sw. [IUCN: Least Concern]
   - *Diplazium porphyrorachis* (Baker) Diels ^
     Restricted distributions: Borneo, Peninsular Malaysia, Sulawesi
   - *Diplazium riparium* Holttum
   - *Diplazium* sp.
   - *Diplazium sylvaticum* (Bory) Sw.
   - *Diplazium vestitum* var. *borneense* (C. Chr.) Holttum #

5. BLECHNACEAE

1. *Blechnopsis*
   - *Blechnopsis finlaysoniana* (Wall. *ex* Hook. & Grev.) C. Presl
   - *Blechnopsis orientalis* (L.) C. Presl

6. CYATHEACEAE

1. *Alsophila*
   - *Alsophila borneensis* (Copel.) R.M. Tryon
   - *Alsophila latebrosa* Wall.
2. *Gymnosphaera*
   - *Gymnosphaera commutata* (Mett.) S.Y. Dong

Gymnosphaera ramispina (Hook.) Copel. #

6.3 *Sphaeropteris*

Sphaeropteris glauca (Blume) R.M. Tryon [IUCN: Least Concern]

Sphaeropteris moluccana (Desv.) R.M. Tryon

7. DAVALLIACEAE

1. *Davallia*

Davallia divaricata Blume

Davallia repens (L. fil.) Kuhn

Davallia sp.

8. DENNSTAEDTIACEAE

1. *Microlepia*

Microlepia speluncae (L.) T. Moore

9. DIPTERIDACEAE

1. *Dipteris*

Dipteris conjugata Reinw.

Dipteris lobbiana (Hook.) T. Moore

10. DRYOPTERIDACEAE

1. *Bolbitis*

Bolbitis sinuata (C. Presl) Hennipman

2. *Pleocnemia*

Pleocnemia irregularis (C. Presl) Holttum

Pleocnemia sp.

3. *Teratophyllum*

Teratophyllum aculeatum (Blume) Mett. ex Kuhn

11. GLEICHENIACEAE

1. *Dicranopteris*

Dicranopteris linearis (Burm. fil.) Underw.

2. *Sticherus*

Sticherus truncatus (Willd.) Nakai

12. HYMENOPHYLLACEAE

1. *Abrodictyum*

Abrodictyum pluma (Hook.) Ebihara & K. Iwats.

2. *Cephalomanes*

Cephalomanes javanicum (Blume) C. Presl

Cephalomanes javanicum var. *asplenioides* (C. Presl) K. Iwats.

Cephalomanes singaporianum Bosch

3. *Crepidomanes*

Crepidomanes bipunctatum (Poir.) Copel.

4. *Hymenophyllum*

Hymenophyllum acanthoides (Bosch) Rosenst.

*Hymenophyllum carduncul*us C. Chr. ^

Restricted distributions: Borneo & the Philippines

Hymenophyllum denticulatum Sw.

Hymenophyllum holochilum (Bosch) C. Chr.

Hymenophyllum serrulatum (C. Presl) C. Chr.

13. LINDSAEACEAE

1. *Lindsaea*
   - *Lindsaea borneensis* Hook.
   - *Lindsaea cultrata* (Willd.) Sw.
   - *Lindsaea divergens* Wall. *ex* Hook. & Grev.
   - *Lindsaea doryphora* K.U. Kramer
   - *Lindsaea ensifolia* Sw.
   - *Lindsaea integra* Holttum
   - *Lindsaea interrupta* (Wall. *ex* Roxb.) C.V. Morton
   - *Lindsaea parallelogramma* Alderw.
   - *Lindsaea* sp.

14. LOMARIOPSIDACEAE

1. *Cyclopeltis*
   - *Cyclopeltis crenata* (Fée) C. Chr.

15. LYGODIACEAE

1. *Lygodium*
   - *Lygodium flexuosum* (L.) Sw.

16. MARATTIACEAE

1. *Angiopteris*
   - *Angiopteris evecta* (G. Forst.) Hoffm.
2. *Christensenia*
   - *Christensenia aesculifolia* (Blume) Maxon

17. NEPHROLEPIDACEAE

1. *Nephrolepis*
   - *Nephrolepis biserrata* (Sw.) Schott

18. OLEANDRACEAE

1. *Oleandra*
   - *Oleandra neriiformis* Cav.

19. POLYPODIACEAE

1. *Ctenopterella*
   - *Ctenopterella blechnoides* (Grev.) Parris
2. *Drynaria*
   - *Drynaria sparsisora* (Desv.) T. Moore
3. *Goniophlebium*
   - *Goniophlebium percussum* (Cav.) Wagner & Grether
4. *Lepisorus*
   - *Lepisorus accedens* (Blume) Hosok.
   - *Lepisorus longifolius* (Blume) Holttum
5. *Leptochilus*
   - *Leptochilus macrophyllus* (Blume) Noot.
6. *Microsorum*
   - *Microsorum membranifolium* (R. Br.) Ching.
   - *Microsorum scolopendria* (Burm. fil.) Copel.

7. *Prosaptia*
   Prosaptia alata (Blume) Christ
8. *Pyrrosia*
   Pyrrosia lanceolata (L.) Farw.
   Pyrrosia longifolia (Burm. fil.) C.V. Morton
9. *Selliguea*
   Selliguea heterocarpa (Blume) Blume
   Selliguea lateritia (Baker) Hovenkamp
   Selliguea stenophylla (Blume) Parris
   Selliguea taeniata (Sw.) Parris
10. *Thylacopteris*
   Thylacopteris papillosa (Blume) Kunze *ex* J. Sm.

20. PTERIDACEAE

1. *Antrophyum*
   Antrophyum callifolium Blume
   Antrophyum sessilifolium (Cav.) Spreng.
2. *Haplopteris*
   Haplopteris ensiformis (Sw.) E.H. Crane
   Haplopteris scolopendrina (Bory) C. Presl
   Haplopteris zosterifolia (Willd.) E.H. Crane
3. *Pityrogramma*
   Pityrogramma calomelanos (L.) Link
4. *Pteris*
   Pteris sp.
5. *Syngramma*
   Syngramma alismifolia (C. Presl) J. Sm.
   Syngramma wallichii (Hook.) Bedd.
6. *Taenitis*
   Taenitis blechnoides (Willd.) Sw.

21. SCHIZAEACEAE

1. *Actinostachys*
   Actinostachys digitata (L.) Wall.
   Actinostachys inopinata (Selling) C.F. Reed
   Actinostachys sp.
2. *Schizaea*
   Schizaea dichotoma (L.) Sm.

22. TECTARIACEAE

1. *Malaifilix*
   Malaifilix grandidentata (Ces.) Li Bing Zhang & Schuettp.
2. *Polydictyum*
   Polydictyum ternatum (Baker) S.Y. Dong & C.W. Chen #
3. *Tectaria*
   Tectaria angulata (Willd.) Copel.
   Tectaria crenata Cav.
   Tectaria fissa (Kunze) Holttum
   Tectaria inopinata Holttum #
   Tectaria palmata var. *platanifolia* (Mett.) Holttum

Tectaria pleiosora (Alderw.) C. Chr.
Tectaria polymorpha (Wall. *ex* Hook.) Copel.

23. THELYPTERIDACEAE

1. Abacopteris
   Abacopteris nitida (Holttum) S.E. Fawc. & A.R. Sm.
2. *Amblovenatum*
   Amblovenatum immersum (Blume) Mazumdar
   Amblovenatum opulentum (Kaulf.) J.P. Roux
3. *Christella*
   Christella arida (D. Don) Holttum
   Christella subpubescens (Blume) Holttum
4. *Mesophlebion*
   Mesophlebion beccarianum (Ces.) Holttum ^
      Restricted distributions: Borneo, Peninsular Malaysia & New Guinea
   Mesophlebion crassifolium (Blume) Holttum
5. *Pronephrium*
   Pronephrium firmulum (Baker) Holttum #
   Pronephrium hosei (Baker) Holttum ^
      Restricted distributions: Borneo & the Philippines
6. *Reholttumia*
   Reholttumia truncata (Poir.) S.E. Fawc. & A.R. Sm.
7. *Sphaerostephanos*
   Sphaerostephanos perglanduliferus (Alderw.) Holttum
   Sphaerostephanos polycarpus (Blume) Copel.
   Sphaerostephanos pterosporus var. *crenatus* Holttum #

APPENDIX 2.

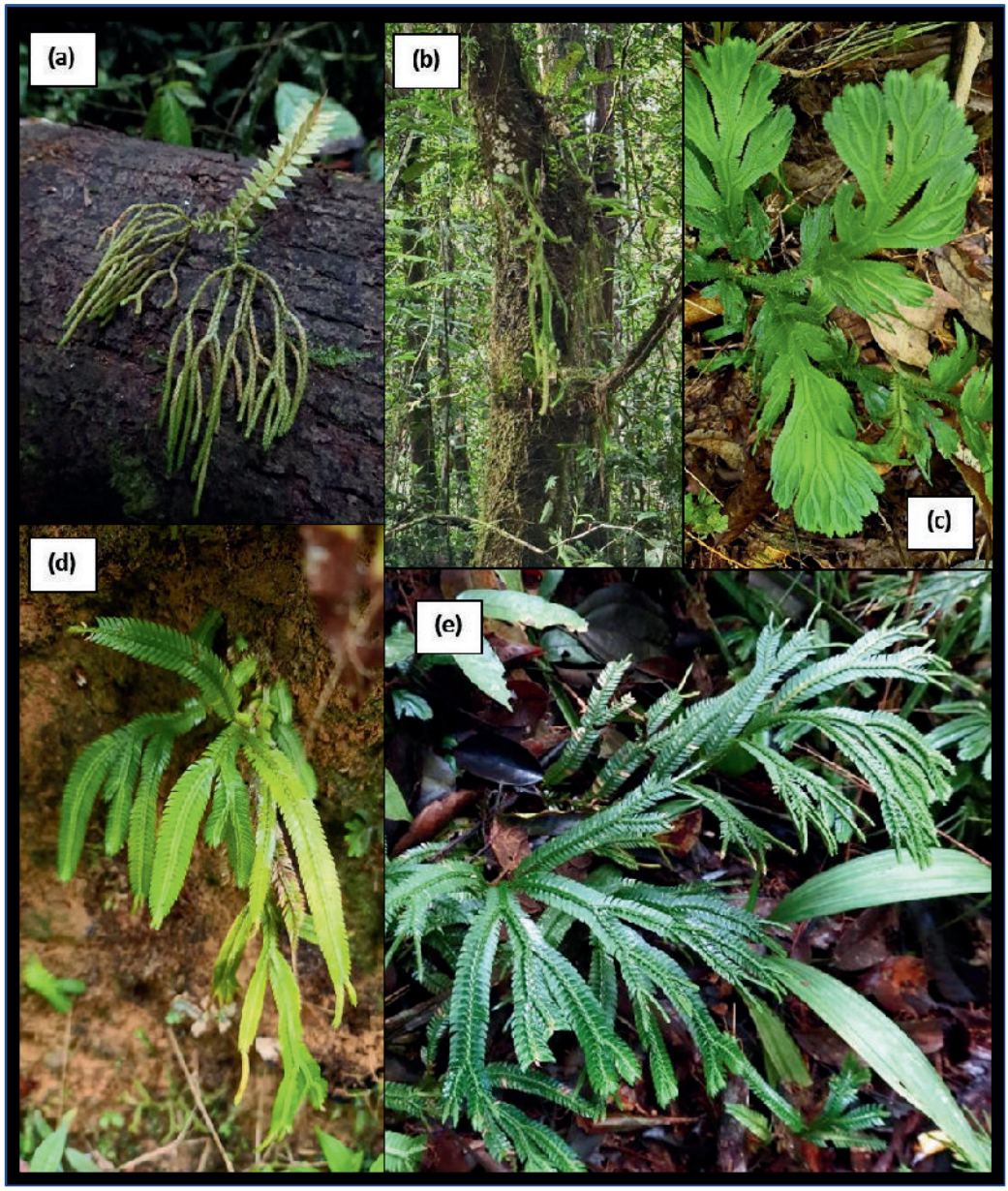


Figure 2. **LYCOPHYTES.** Lycopodiaceae: (a) *Phlegmariurus phlegmaria* (b) *Phlegmariurus squarrosus*; Selaginellaceae: (c) *Chuselaginella grandis* (d) *Chuselaginella brooksii* (e) *Chuselaginella alopecuroides* #

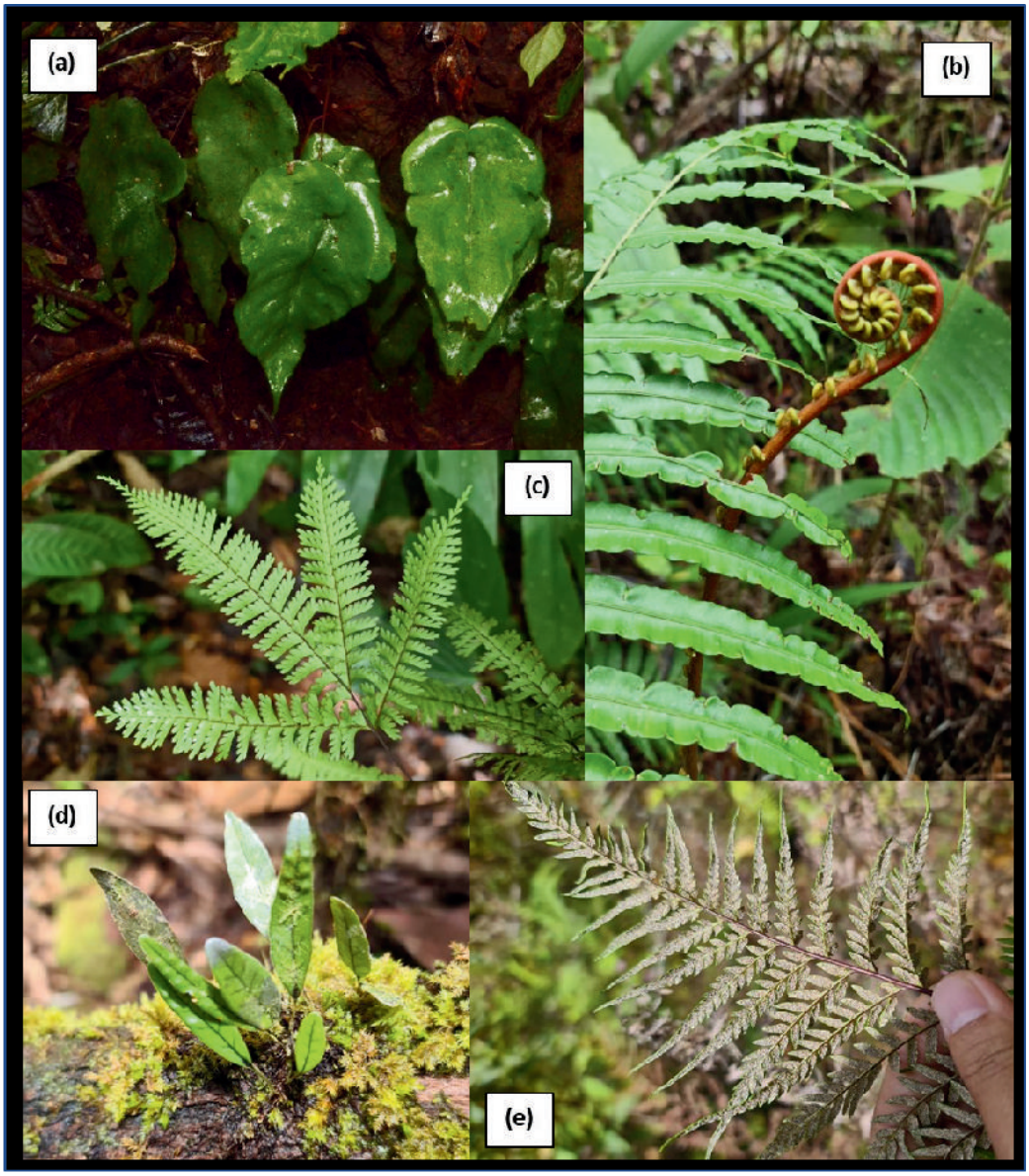


Figure 3. FERNS. Tectariaceae: (a) *Tectaria inopinata* #; Blechnaceae: (b) *Blechnopsis finlaysoniana*; Lindsaeaceae: (c) *Lindsaea parallelogramma*; Polypodiaceae: (d) *Selliguea lateritia*; Pteridaceae: (e) *Pityrogramma calomelanos*

DIVERSITY OF PANDANACEAE IN GERENAI-LONG MEKABA, MIRI

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Abstract: This study provides a glimpse on the diversity in the family of Pandanaceae, especially at the North-Eastern of Sarawak. A total of ten Pandanaceae species consisting of three *Benstonea* species, six *Freycinetia* species and a *Pandanus* species were recorded within the Gerenai – Long Mekaba areas. Two of the species were acknowledged to be new locality records to Miri Division. Furthermore, a *Benstonea* species was noted to be utilized by the Kenyah of Long Mekaba. The data presented here are anticipated to enrich the present knowledge of the Pandanaceae species in Sarawak.

Keywords: Pandanaceae, *Benstonea, Freycinetia*

1 INTRODUCTION

Sarawak has one of the oldest rainforests that holds rich biodiversity including thousands of plant species. More species of flora are yet to be discovered or documented, especially within the remote areas under the Heart of Borneo (HoB) initiative. This includes the plant family of Pandanaceae that is considered to be understudied. Currently, an official list of species checklist of Pandanaceae in Sarawak is absent despite its abundance and wide distributions in various habitats. Thus, this study was conducted to investigate the species richness of Pandanaceae in the forests of Generai- Long Mekaba and to obtain some insights on the species diversity and taxonomy of the plant group within the areas. The data presented here are anticipated to enrich the present knowledge of the Pandanaceae species in Sarawak.

2 METHODOLOGY

Field samplings were conducted during the 9th Scientific Heart of Borneo (HoB) expedition at Trail 1, Trail 6, Trail 9, Trail 11, Trail 12, Trail 13, Trail 14, Trail 16, and along the roadsides of Gerenai-Long Mekaba. The sighted Pandanaceae species were photographed and their GPS coordinates were documented. The recorded species were collected and preserved as herbarium voucher specimens based on techniques by Stone (1983) and Bridson and Forman (1992). The morphological characteristics of the collected samples were observed, characterized, and identified accordingly based on the guidelines provided by Stone (1970), Stone (1993) and Callmander et al. (2012).

3 RESULTS AND DISCUSSION

The Majority of the sighted individuals were not in their reproductive stages. Therefore, this study was only focusing on the plants with reproductive structures and distinctive characters that were collected and inventoried. A total of ten Pandanaceae species consisting of three *Benstonea* species, six *Freycinetia* species and a *Pandanus* species were recorded within the Gerenai – Long Mekaba areas. The record of two species, *thomissophylla* and *Freycinetia kalimantanica*, at Gerenai-Mekaba areas revealed the new locality record for the species in Miri Division. On the other hand, additional data on ethnobotanical uses by the Kenyah ethnic was able to be recorded in Long Mekaba; on the utilization of *Benstonea sylvatica* leaves as material for mat-making (Leaman, 1996; Hendra et al., 2020). Furthermore, the species was believed to have edible fruit, making it an attractive addition to the list of nutritionally valuable Pandanaceae species (Nadaf et al., 2012; Bhandary, 2022).

The overall findings on the diversity of Pandanaceae species in Gerenai–Long Mekaba areas were:

1. Benstonea thomissophylla (B. C. Stone) Callm. & Buerki (Figure. 1)

Morphological characteristics: Small pandan growing approximately to 1 m tall; leaves with caducous, brown auricles; infructescence erect, bearing solitary cephalium with green pileus cap and pale green, ascending style and brown stigma.

Habitat: Growing on the ridge top, at an elevation of more than 500 m above sea level.

Ethnobotany: Unknown.

Distribution: Endemic to Sarawak.

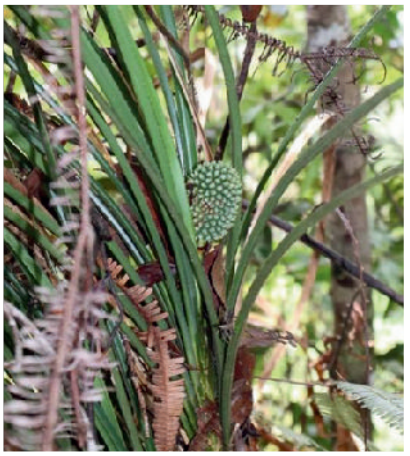


Figure 1*: Benstonea thomissophylla*

3.2. *Benstonea sylvatica (B. C. Stone) Callm. & Buerki* (Figure 2)

Morphological characteristics: Solitary; infructescence erect bearing ~~a~~–green, subglobose to ellipsoid cephalium with distinctive glaucous pileus cap. The mature cephalia produces a nutty smell when dissected.

Habitat: Growing on the hillslope at the forest fringes and along the river.

Ethnobotany: This pandan is a common pandan found in the Long Mekaba area and was also known as "*Da' ah*" by the Kenyah community. ccording to the local community in the area, other than being utilize d as an alternative material for mat-making, the fruit or the cephalia of the species is edible and reportedly has a sweet taste. However, it was only eaten in small amounts.

Distribution: Endemic to Sarawak

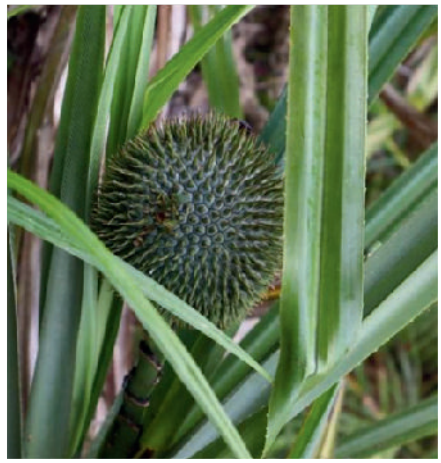


Figure 2: *Benstonea sylvatica*

3.3. ***Benstonea cf. sylvatica*** (Figure 3)

Morphological characteristics: Leaves apex cuspidate, acumen about 11 cm long. Infructescence bearing a solitary, green and subglobose cephalium with undulate stigma.

Habitat: Growing on rocks in the forest.

Notes: Suspected to be a new record for Sarawak. Further investigation is needed.

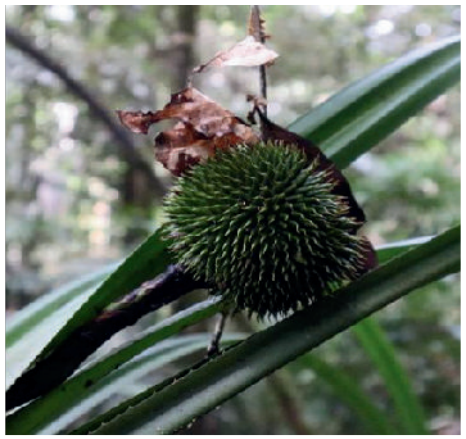


Figure 3: *Benstonea* cf. *Sylvatica*

3.4. ***Freycinetia cf. creaghi Hemsl***. (Figure 4)

Morphological characteristics: Leaves with completely unarmed abaxial midrib and caducous, papery auricles. Infructescence consists of three to four subglobose to ellipsoid cephalia, each with three to six (commonly in four), brown stigmas.

Habitat: Riverine forest.

Notes: Further investigation is needed to determine the species.



Figure 4: *Freycinetia* cf. *Creaghi*

3.5. ***Freycinetia sp. 1*** **(Figure 5)**

Morphological characteristics: Leaves elliptic with membranous, caducous, brown auricles. Infructescence bearing three cylindrical cephalia with three to six, dark brown stigmas (commonly in three)

Habitat: Riverine Forest.

Notes: Further investigation is needed to determine the species.



Figure 5: *Freycinetia* sp. 1

3.6. ***Freycinetia kalimantanica B. C. Stone*** (Figure 6)

Morphological characteristics: Leaves coriaceous with membranous, pale brown auricles. Infructescence consists of four subellipsoid or reniform cephalia; pale orange; two to six stigmas (commonly in four); scabrous pedicel.

Habitat: Riverine Forest.

Distribution: Borneo



Figure 6: *Freycinetia kalimantanica*

3.7. ***Freycinetia rigidifolia Hemsl***. (Figure 7)

Morphological characteristics: Staminate inflorescence with distinctive red bracts.

Habitat: Hillslope at the forest fringe.

Distribution: Andaman Islands to West Malesia



Figure 7*: Freycinetia rigidifolia*

3.8. *Freycinetia cf. sumatrana Hemsl.* (Figure 8)

Morphological characteristics: Robust plant with tapered, caducous, pale brown auricles.

Habitat: Hillslope at the forest fringe.

Notes: Further investigation is needed to determine the species.



Figure 8*: Freycinetia* cf. *Sumatrana*

3.9. *Freycinetia sp. 2* (Figure 9)

Morphological characteristics: Leaves linear with white marginal spines; stem thick and long, covered with old dead leaves.

Habitat: Hillslope at the forest fringe.

Notes: Further investigation is needed to determine the species.



Figure 9*: Freycinetia* sp. *2*

3.10. *Pandanus cf. dorystigma*

Morphological characteristics: Marscencent stem. Linear leaves with reddish leaf basal.

Habitat: Growing in clumps, in/near the river.

Notes: Photographs were not able to be captured due to the strong river currents.

4 CONCLUSION

This study provides a glimpse of the diversity in the family of Pandanaceae especially in the North-Eastern of Sarawak. It is suggested Gerenai-Long Mekaba should serve as important research sites for the plant group – especially for the *Freycinetia* species that are recognized as dominant species in the areas.

ACKNOWLEDGEMENT

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DISTRIBUTION OF *THISMIA* SPECIES (THISMIACEAE) MYCOHETEROTROPHIC HERBS IN SARAWAK WITH A NEW RECORD SPECIES FROM LONG MEKABA

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Abstract: The genus *Thismia*, also known as fairy lantern, is a small monocotyledonous plant related to mycorrhizal fungi and found mainly in tropical and subtropical forests. Of the approximately 107 known species, 39 are native to Malaysia, 16 of which are native to Sarawak. Of the species in Sarawak, three (3) are shared with the neighbouring state of Sabah, while Sarawak and Peninsular Malaysia share two (2) species. Most of the *Thismia* species are only known from their original locations and in some cases, they have only been observed from a few individuals. However, some of the species from Sarawak have a wider distribution range and have been rediscovered after many years. Normally, *Thismia* species are considered extremely rare and are restricted to certain areas. However, due to their inconspicuous appearance and short-lived growth, they are easily overlooked in the wild. During the HOB expedition, *Thismia pallida* was recorded in Long Mekaba, Gerenai FMU, a species new record to Sarawak. This article provides an insight into the species diversity and distribution of the genus *Thismia* in Sarawak.

Keywords: Borneo, diversity, fairy lantern.

1 INTRODUCTION

Thismia (family *Thismia*ceae) is a genus of mycoheterotrophic plants. The genus comprises 107 species (Imhof, 2010 onwards) and distributed in tropical and subtropical Asia, northern and eastern Australia to New Zealand, the north-central states of the USA, Costa Rica and southern tropical America (POWO, 2023). Two main centers of their diversities in Southeast Asia are located in Malay Peninsula and Borneo. Most species have very small distribution ranges, only a few species are widespread and some species have only been collected once. *Thismia* species are restricted from secondary to primary rainforests, where they grow in specific locations and can only be seen during the flowering or fruiting phase. Due to their small size, even the flowering phase of young buds or roots can be easily overlooked. *Thismia* relies on its relationship with fungi to obtain its nutrients. *Thismia* is a mycoheterotrophic plant

that depends on fungi for its nutrient supply. There are about 39 known species in Malaysia: 21 in Peninsular Malaysia and 16 in Sarawak. In Sarawak, *Thismia* species are only found in a few places. They are found in dipterocarp lowland forests, dipterocarp montane forests and montane forests. Taxonomically, the genus *Thismia* in the Malesia region was revised by Jonker (1948). Currently, the current list is being updated on the mycoheterotrophic plants website by Imhof. Recently, many new species have been discovered in Peninsular Malaysia (Siti-Munirah *et al*., 2022; Siti-Munirah & Dome, 2023). In Sarawak, the species diversity has rather increased since 2015 as many new discoveries were described by Hroneš et al. (2015, 2018), Dančák *et al*., (2018, 2020a, 2020b, 2020c) and Sochor *et al*., (2018a, 2018b). From 12 to 25 September 2022, a scientific Heart of Borneo (HoB) expedition was conducted in Long Mekaba, Gerenai FMU. During the HoB expedition, a new record species to Sarawak was discovered. *Thismia pallida* was discovered in Long Mekaba, Gerenai FMU. Previously, *T. pallida* had only been found in Sabah.

2 METHODOLOGY

The data contained in this study were obtained from the literature, examination of herbarium specimens at the Forest Research Institute Malaysia, Kepong Herbarium (KEP), Long Mekaba's collection and images from various sources. Distribution maps for *Thismia* species in Sarawak were prepared based on locality data entered into the Botanical Research and Herbarium Management System (BRAHMS) database software, taking into account the current data from the field and literature. The morphological characteristics of the specimens from Long Mekaba were analyzed using a stereomicroscope and high-resolution macrophotography. The measurements were carried out on fresh and liquid-preserved material. The specimens were thoroughly compared with original drawings and descriptions in the protocols of *Thismia.*

3 FINDINGS

This report is based on information from various sources. We have also officially reported here the occurrence of *Thismia pallida* in Sarawak (Figure 1). Based on recent publications (Table 1: protologues and references) and the findings from Long Mekaba, the following *Thismia* species are currently listed in Sarawak, with an additional new finding of *T. pallida*;

Table 1. List of the diversity of *Thismia* species in the state of Sarawak

Species	**Protologues / Reference**
Thismia neptunis Becc.,	Malesia 1: 251 (1878).
Thismia ophiuris Becc.,	Malesia 1: 252 (1878).
Thismia clavigera F.Muell.,	in Proc. Roy. Soc. Tasm. 1890 (1891) 235; et ex Bot. Centralbl. xlvi. (1891) 141.
Thismia episcopalis F.Muell.,	in Proc. Roy. Soc. Tasm. 1890 (1891) 235; et ex Bot. Centralbl. xlvi. (1891) 141.
Thismia bifida M.Hotta,	Acta Phytotax. Geobot. 22(4-6): 161 (1967).
Thismia goodii Kiew	Gard. Bull. Singapore 51(2): 179 (1999).
Thismia brunneomitra Hroneš, Kobrlová & Dančák,	Phytotaxa 234(2): 173 (2015).
Thismia cornuta Hroneš, Sochor & Dančák,	Pl. Ecol. Evol. 151(1): 111 (2018).
Thismia acuminata Hroneš, Dančák & Sochor,	Pl. Syst. Evol. 304(5): 705 (2018).
Thismia laevis Sochor, Dančák & Hroneš,	Pl. Syst. Evol. 304(5): 708 (2018).
Thismia nigra Dančák, Hroneš & Sochor,	Pl. Syst. Evol. 304(5): 711 (2018).
Thismia viridistriata Sochor, Hroneš & Dančák,	Pl. Syst. Evol. 304(5): 714 (2018).
Thismia kelabitiana Dančák, Hroneš & Sochor,	PLoS ONE 13(10): e0203443 (3) (2018).
Thismia ornata Dančák, Hroneš & Sochor,	Willdenowia 50(1): 66 (2020)
Thismia coronata Hroneš, Dančák & Sochor,	Willdenowia 50(1): 71 (2020).
Thismia minutissima Dančák, Hroneš & Sochor,	Kew Bull. 75(2)-29: 2 (2020).
Thismia pallida Hroneš, Dančák & Rejžek,	Pl. Ecol. Evol. 151(1): 115. 2018.



Figure 1. The photos above show close-ups of *Thismia pallida* found in Long Mekaba and a comparison with the original *T. pallida* from Sabah (Photos by Siti M-Munirah MY).

The distribution patterns of *Thismia* species in Sarawak show a good result for the area where ecological preferences and possible interactions with certain fungal partners could be determined in addition to the occurrence of *Thismia* (Figure 2). The discovery of a species that is new record to Sarawak from Long Mekaba emphasizes the importance of comprehensive field studies in less explored regions.

The ecological impact of mycoheterotrophic plants and their role in forest ecosystems is also a potential research aspect that needs to be further explored. Understanding the distribution and ecological requirements of *Thismia* species is crucial for effective conservation strategies. The presence of a newly recorded species in Long Mekaba emphasizes the need for targeted conservation measures in this region. Conservation initiatives should take into account the specific requirements of mycoheterotrophic plants to ensure the conservation of their habitats. Of the species in Sarawak, three (3) species are shared with the neighbouring state of Sabah (Figure 3), while Sarawak and Peninsular Malaysia share two (2) species (*Thismia clavigera* and *Thismia ornata*).

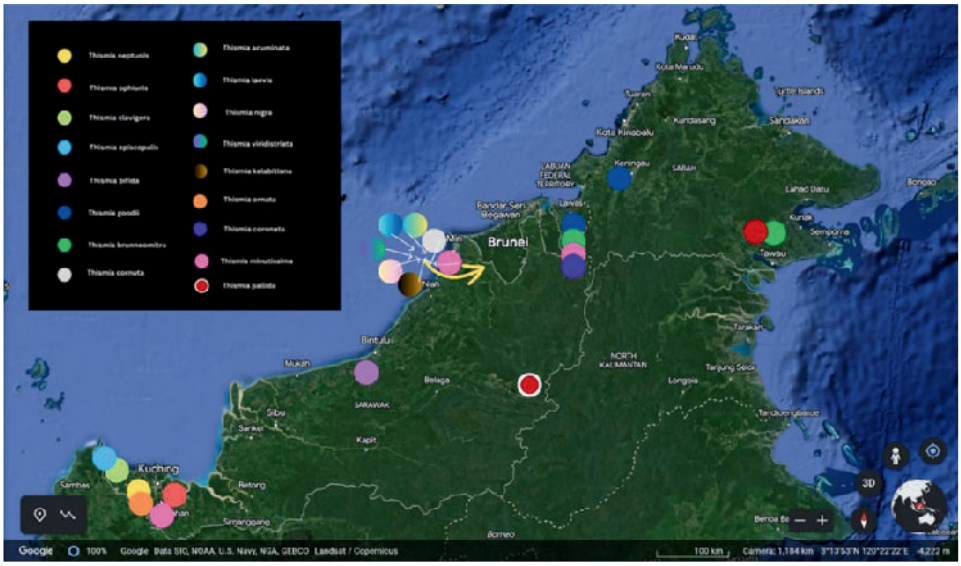


Figure 2. The distribution area of the *Thismia* species in Sarawak

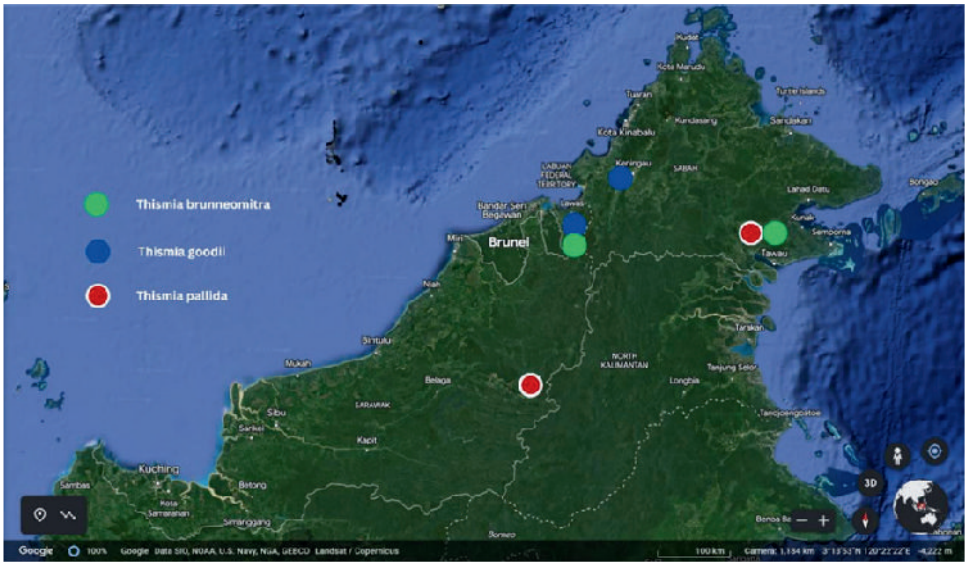


Figure 3. The distribution area of the *Thismia* species is shared with the neighbouring state of Sabah.

Here we have listed the current conservation status (Table 2) based on the references (and protologues) listed in Table 1. The conservation status of some species has not yet been assessed in the past. For the species that have been assessed in the past, the conservation status of most species is threatened for various reasons, e.g. deforestation, land-use change or habitat in unprotected areas. In addition, 13 of the 17 species are endemic to Sarawak.

Table 2. Conservation status of *Thismia* in Sarawak

Species	Conservation Status
Thismia neptunis	EN B2ab(iii).
Thismia ophiuris	Not Evaluated
Thismia clavigera	Not Evaluated
Thismia episcopalis	Not Evaluated
Thismia bifida	Not Evaluated
Thismia goodii	CR B2ab (ii, iii, iv)
Thismia brunneomitra	EN B2ab (iii)
Thismia cornuta	EN B2ab (iii,v)
Thismia acuminata	CR D
Thismia laevis	CR D
Thismia nigra	(EN) D
Thismia viridistriata	(EN) C2ai
Thismia kelabitiana	CR B2ab (iii,iv,v) and C2a(i)
Thismia ornata	VU (D1+2)
Thismia coronata	CR (B2ab(iii); D)
Thismia minutissima	VU D1+D2
Thismia pallida	CR

Notes: CR = Critically Endangered; EN = Endangered; VU = Vulnerable

4 DISCUSSION

This report represents a significant milestone in our endeavour to unravel the intricate distribution patterns of *Thismia* species in Sarawak and sheds light on the rich biodiversity of the region. The discovery of a new recorded species in Long Mekaba is a testament to the unexplored areas in Sarawak and emphasizes the urgency of thorough exploration. These new findings not only contribute to the understanding of plant biodiversity, but also emphasize the crucial role of mycoheterotrophic herbs in Sarawak's ecosystems. In terms of conservation, it is clear that further research in less explored regions is essential to uncover and protect the hidden plant species that remain threatened with extinction. Many new discoveries in Sarawak were made in recent years by a group of researchers (Dančák et al., 2020) and the recent new record from Long Mekaba show that further exploration is needed in these areas. The

identification of a new species or record of *Thismia* in this region opens up the possibility of discovering more hidden treasures in the less explored corners of Sarawak. This report has shown that a glimpse understanding of the distribution of *Thismia* species requires detailed research and documentation.

5 CONCLUSION

This study represents a significant advance in the study of *Thismia* species in Sarawak. The discoveries at Long Mekaba emphasize the need for detailed exploration of less explored regions, while the need for complete material, the involvement of local naturalists and the application of molecular studies further enrich our understanding. By exploring the intricate world of *Thismia*, our efforts not only contribute to a broader understanding of plant biodiversity but also have conservation implications by emphasizing the need to uncover and protect the hidden plant diversity that thrives in the unexplored corners of Sarawak.

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A CONCISE MOSS CHECKLIST OF GERENAI-LONG MEKABA AREA, SARAWAK BUMI KENYALANG

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Abstract: This paper outlines the findings of a 14-day survey conducted in year 2022 during the 9th Heart of Borneo Scientific Expedition, investigating the moss flora of the Gerenai-Long Mekaba area. Around 598 samples were collected, marking the first and sole study conducted in this region. Of these, a total of 105 species and three (3) varieties in 47 genera and 21 families were determined. This represents roughly one-third of the 330 taxa found in Sarawak or approximately 15% of the 721 taxa documented for Borneo. Thirteen taxa of mosses are reported new to Sarawak region. Notably, the discovery of *Distichophyllum kinabaluense* Nog. & Z. Iwats. beyond its native habitat is a noteworthy finding. Besides that, rare species like *Neckeropsis fleischeri* (Dixon) Touw, *Papillidiopsis bruchii* (Dozy & Molk.) W.R. Buck & B.C. Tan and *Sclerohypnum littorale* (Hampe) B.C. Tan, are frequently encountered within the Gerenai-Long Mekaba area, indicating the high conservation value of this area.

Keywords: Bryophyte, Heart of Borneo, Conservation, Endemic, Rare species.

1 INTRODUCTION

Long Mekaba (N 2° 54-57', E 114° 55-59') lies in the Heart of Borneo region, is part of the Gerenai Forest Management Unit (FMU), located specifically in the Batang Baram-Sungai Silat area of the Long Lama sub-district, Telang Usan district, Miri division, North-Eastern Sarawak. The study area emphasized the origin of Sg. Akah, that was feeding into the Baram River. Geologically, this area falls within the category of Kelabit Formation, the oldest rock formation in the interior part of Sarawak, and it is mainly composed of mudstone, with occasional inter-beddings of sandstones and siltstones (Haile, Adams & Haak, 1962). Thus far, there is no major botanical survey of this Gerenai-Long Mekaba area, and this report served as the sole and first record of the moss diversity of that area. The expedition set off from Miri and travelled to a small town named Long Lapok, then later Long Mekaba. The journey was solely on logging roads beginning from Long Lapok to Long Mekaba. The total journey required was approximately seven hours. Encompassed by patches of both virgin and logged-over forests,

the area results in a mix of dipterocarp forest with riverbank vegetation and old shifting cultivation sites.

2 MATERIALS AND METHODS

This study was based on the moss samples collected during the 9th Heart of Borneo Scientific Expedition from 14 to 23 September 2022 (Table 1). Random sampling was carried out along the designated transects of the research site. All the collected specimens were curated, labelled, and deposited in the Herbarium of Universiti Malaya (KLU) with duplicates in the Herbarium of Forest Department Sarawak (SAR).

3 LAND DISCUSSION

A total of 105 species and three varieties in 47 genera and 21 families were determined during this study. This represents roughly one-third of the 330 taxa found in Sarawak or approximately 15% of the 721 taxa documented for Borneo (Suleiman, Akiyama & Tan, 2006). The predominant family in this region is Calymperaceae, boasting 27 species and infraspecies, which includes a Bornean endemic species, *Syrrhopodon teniolatus* L.T. Ellis. Following closely, Sematophyllaceae stands as the second most diverse family with 18 species and infraspecies. Together, these two families contribute to approximately 41.6% of the total moss diversity in the area. Remarkably, 13 species and infraspecies identified during this study are new records for Sarawak, highlighting the botanical importance of this area.

The study unveils significant discoveries: the discovery of *Distichophyllum kinabaluense* Nog. & Z. Iwats., previously endemic to the highlands of Mt. Kinabalu (Noguchi & Iwatsuki, 1972), is now observed in the study area. This represents the first recorded occurrence of the species beyond its native habitat and thriving in a lowland area like Gerenai-Long Mekaba, indicating the unique topography and pristine environment of inland Sarawak can also be the home for some highland plant species. Furthermore, rare moss species like *Fissidens pallidus* Hook. f. & Wilson, *Mitthyridium retusum* (Besch.) W.D. Reese, *Papillidiopsis bruchii* (Dozy & Molk.) W.R. Buck & B.C. Tan and *Pogonatum rutteri* (Thér. & Dixon) Dixon are some of the important findings in the surveyed area. In addition, several rare species with conservation significance were found to be surprisingly abundant within the study area, namely *Neckeropsis fleischeri* (Dixon) Touw, *Papillidiopsis bruchii* (Dozy & Molk.) W.R. Buck & B.C. Tan, *Sclerohypnum littorale* (Hampe) B.C. Tan (Figure 1E & G). Meanwhile, several common lowland species were found to be unusually infrequent and present in very low abundance, for instance, *Aerobryopsis longissima* (Dozy & Molk.) M.Fleisch. and *Pyrrhobryum latifolium* (Bosch & Sande Lac.) Mitt. (Figure 1F).

A comparative analysis of the moss diversity reported between different forested areas, viz., Lanjak-Entimau Wildlife Sanctuary (Majid et al., 2011) and Gunung Serapi (Mohamed, Yong & Bakar, 2003) is provided in Table 2. The species and their corresponding moss families have been reorganized for Mount Serapi and Lanjak Entimau Wildlife Sanctuary, adhering to the extant moss genera outlined by Goffinet and Buck (2024). It reveals that the moss diversity at Gerenai-Long Mekaba is notably greater than that of Gunung Serapi yet falls below that of Lanjak-Entimau Wildlife Sanctuary. Further research is required to understand the different

species richness observed in the above areas. Nevertheless, Calymperaceae and Sematophyllaceae are the two most represented families in all three areas (Table 2).

4 CONCLUSION

The Gerenai-Long Mekaba area houses a rich moss diversity comparable to any of the good lowland forests in Borneo (Mohamed et al., 2003; Majid et al., 2011) and Peninsular Malaysia (Damanhuri et al., 2005; Mohamed & Yong, 2007). The total moss diversity stands at 105 species and three varieties in 47 genera and 21 families. The study is botanically important, with high conservation value with the presence of many interesting and are moss species. Future studies could investigate the reasons for the low representation of some common moss species in this area.

Table 1: Collection dates and collection sites of moss specimens taken.

Collection date	Details on the collection site
Sept 14, 2022	Area adjacent to Sungai Mekaba (N 2°54-55'; E 114°56'), Transect no. 10.
Sept 15, 2022	Area adjacent to Sungai Silat (N 2°54-55'; E 114°56'), Transect no. 16.
Sept 16, 2022	Riverbank vegetation along Sungai Mekaba (N 2°54-55'; E 114°55-56'), Transect no. 11 & 12.
Sept 17, 2022	Hill forest adjacent to a shifting cultivation area (N 2°55'; E 114°56-57'), Transect no. 7.
Sept 18, 2022	Area between Sungai Mekaba & Sungai Silat (N 2°54-55'; E 114°56'), Transect no. 15.
Sept 19, 2022	Hill forest (N 2°55-56'; E 114°58-59'), Transect no. 2.
Sept 20, 2022	Hill forest (N 2°55-56'; E 114°58-59'), Transect no. 1.
	Riverbank vegetation along Sungai Sebua (N 2°55-57'; E 114°57-59'), Transect no. 5.
Sept 21, 2022	Hill forest adjacent to a shifting cultivation area (N 2°55'; E 114°56-57'), Transect no. 8.
Sept 22, 2022	Vicinity of a small waterfall joins to Sungai Silat and its upstream areas (N 2°56-57'; E 114°56').
	Vicinity of a small waterfall joins to Sungai Sebua and its upstream areas (N 2°56-57'; E 114°57').
	Roadside vegetation along the road to Long Mo (N 2°56-57'; E 114°56-58').
Sept 23, 2022	Riverbank vegetation along Sungai Mekaba (N 2°54-55'; E 114°55-56'), Transect no. 12 & 13.

Table 2: Comparison of the moss diversity reported for Gerenai-Long Mekaba area, Lanjak Entimau Wildlife Sanctuary and Gunung Serapi.

	Families	Gerenai-Long Mekaba		Lanjak-Entimau (Majid *et al.*, 2011)		Gunung Serapi (Mohamed *et al.*, 2003)	
		Genera	Species	Genera	Species	Genera	Species
1	**Bartramiaceae**	-	-	1	2	1	2
2	**Bryaceae**	-	-	1	2	-	-
3	**Calymperaceae**	6	27	6	33+1 subsp.	6	21
4	**Daltoniaceae**	2	5	3	11	2	5
5	**Dicranaceae**	-	-	-	-	1	1
6	**Dicranellaceae**	1	2	-	-	-	-
7	**Diphysciaceae**	1	1	1	1	1	1
8	**Fissidentaceae**	1	8	1	6+2 var.	1	1
9	**Hypnaceae**	6	13	6	11	1	2
10	**Hypnodendraceae**	1	1	1	1	1	1
11	**Hypopterygiaceae**	1	1	1	1	-	-
12	**Leucobryaceae**	1	3+1 var.	3	6	2	6
13	**Meteoriaceae**	2	2	2	2	2	2
14	**Myuriaceae**	1	1	-	-	-	-
15	**Neckeraceae**	3	3	4	6	-	-
16	**Orthotrichaceae**	-	-	-	-	1	3
17	**Phyllodrepaniaceae**	-	-	1	1	1	1
18	**Pilotrichaceae**	1	1+1 var.	1	1+1 var.	1	1+1 var.
19	**Polytrichaceae**	1	4	1	2	-	-
20	**Plagiotheciaceae**	-	-	-	-	1	1
21	**Pottiaceae**	1	1	1	1	1	1
22	**Pterobryaceae**	-	-	1	1	-	-
23	**Ptychomniaceae**	1	2	1	2	1	2
24	**Pylaisiadelphaceae**	6	8	4	10	4	7
25	**Rhizogoniaceae**	1	1	1	1	1	2
26	**Sematophyllaceae**	8	17+1 var.	7	15	6	12
27	**Symphyodontaceae**	1	3	2	4	1	3
28	**Thuidiaceae**	1	1	3	5	-	-
	Total mosses	**47**	**105+3 var.**	**53**	**125+1 subsp.+3 var.**	**36**	**75+1 var.**

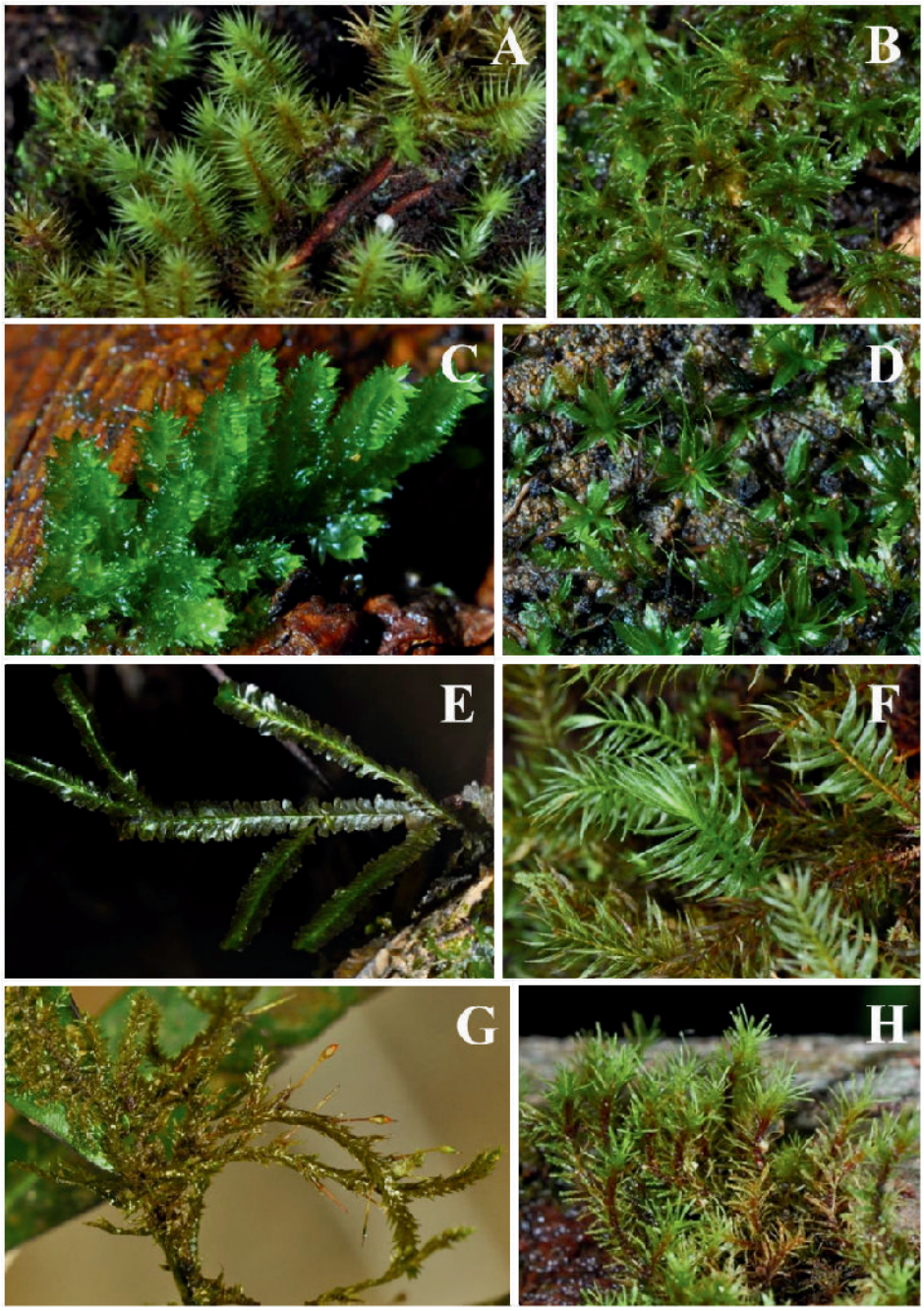


Figure 1: A, *Acroporium convolutum* (Sande Lac.) M. Fleisch.; B, *Calymperes porrectum* Mitt.; C, *Chaetomitrium setosum* Broth. ex Dixon; D, *Diphyscium mucronifolium* Mitt. ex Dozy & Molk.; E, *Neckeropsis fleischeri* (Dixon) Touw; F, *Pyrrhobryum latifolium* (Bosch & Sande Lac.) Mitt.; G, *Sclerohypnum littorale* (Hampe) B.C. Tan; *H, Syrrhopodon hispidissimus* Dixon.

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APPENDICES

APPENDIX: Species Checklist

Asterisk '*' indicates species new to Sarawak.

1. CALYMPERACEAE

1. *Arthrocormus schimperi* (Dozy & Molk.) Dozy & Molk.
2. *Calymperes boulayi* Besch.
3. *Calymperes fasciculatum* Dozy & Molk.
4. *Calymperes lonchophyllum* Schwägr. subsp. *beccari* (Hampe) M. Menzel
5. *Calymperes porrectum* Mitt. (Figure 1B)
6. *Exostratum blumii* (Nees ex Hampe) L.T. Ellis
7. *Leucophanes candidum* (Schwägr.) Lindb.
8. *Leucophanes octoblepharoides* Brid.
9. *Mittlyridium constrictum* (Sull.) H. Rob.
10. *Mittlyridium fasciculatum* (Hook. & Grev.) H. Rob. subsp. *obtusifolium* (Lindb.) M. Menzel
11. *Mittlyridium flavum* (Müll. Hal.) H. Rob.
12. *Mittlyridium jungquilianum* (Mitt. ex Dozy & Molk.) H. Rob.
13. **Mittlyridium retusum* (Besch.) W.D. Reese
14. *Mittlyridium undulatum* (Dozy & Molk.) H. Rob.
15. *Syrrhopodon albovaginatus* Schwägr.
16. **Syrrhopodon cavifolius* Sande Lac.
17. *Syrrhopodon ciliatus* (Hook.) Schwägr.
18. *Syrrhopodon confertus* Sande Lac.
19. *Syrrhopodon croceus* Mitt.
20. *Syrrhopodon hispidissimus* Dixon (Figure 1H)
21. *Syrrhopodon loreus* (Sande Lac.) W.D. Reese
22. *Syrrhopodon muelleri* (Dozy & Molk.) Sande Lac.
23. *Syrrhopodon parasiticus* (Sw. ex Brid.) Besch.
24. *Syrrhopodon prolifer* Schwägr.
25. *Syrrhopodon spiculosus* Hook. & Grev.
26. *Syrrhopodon teniolatus* L.T. Ellis

1.27. *Syrrhopodon tristichus* Nees ex Schwägr.

2. DALTONIACEAE

1. *Distichophyllum brevicuspis* M. Fleisch.
2. *Distichophyllum cuspidatum* (Dozy & Molk.) Dozy & Molk.
3. *Distichophyllum jungermannioides* (Müll. Hal.) Bosch & Sande Lac.
4. **Distichophyllum kinabaluense* Nog. & Z. Iwats.
5. *Ephemeropsis tjibodensis* K.I. Goebel

3. DICRANELLACEAE

1. *Leptotrichella brasiliensis* (Duby) Ochyra
2. *Leptotrichella miqueliana* (Mont.) Lindb. ex Broth.

4. DIPHYSCIACEAE

1. *Diphyscium mucronifolium* Mitt. ex Dozy & Molk. (Figure 1D)

5. FISSIDENTACEAE

1. *Fissidens ceylonensis* Dozy & Molk.
2. *Fissidens crassinervis* Sande Lac.
3. *Fissidens crispulus* Brid.
4. *Fissidens javanicus* Dozy & Molk.
5. *Fissidens pallidus* Hook. f. & Wilson
6. **Fissidens pellucidus* Hornsch.
7. **Fissidens serratus* Müll. Hal.
8. **Fissidens* cf. *taxifolius* Hedw.

6. HYPNACEAE

1. *Ctenidiadelphus plumularia* (Müll. Hal.) M. Fleisch.
2. *Ectropothecium* cf. *chamissonis* (Hornsch.) A. Jaeger
3. *Ectropothecium dealbatum* (Reinw. & Hornsch.) A. Jaeger
4. *Ectropothecium eleganti-pinnatum* (Müll. Hal.) A. Jaeger
5. *Ectropothecium incubans* (Reinw. & Hornsch.) A. Jaeger

6. *Ectropothecium* sp.

7. *Hypnum* sp.

8. *Phyllodon bilobatus* (Dixon) P.E.A.S. Câmara

9. *Sclerohypnum littorale* (Hampe) B.C. Tan (Figure 1G)

10. *Vesicularia dubyana* (Müll. Hal.) Broth.

11. *Vesicularia miquelii* (Sande Lac.) M. Fleisch.

12. *Vesicularia montagnei* (Bél.) Broth.

13. *Vesicularia reticulata* (Dozy & Molk.) Broth.

7. HYPNODENDRACEAE

1. *Hypnodendron subspininervium* (Müll. Hal.) A. Jaeger

8. HYPOPTERYGIACEAE

1. *Hypopterygium flavolimbatum* Müll. Hal.

9. LEUCOBRYACEAE

1. *Leucobryum bowringii* Mitt.

2. *Leucobryum javense* (Brid.) Mitt.

3. **Leucobryum sanctum* (Nees ex Schwägr.) Hampe var. *arfakianum* (Müll. Hal. ex Geh.) A. Eddy

4. *Leucobryum sanctum* (Nees ex Schwägr.) Hampe var. *sanctum*

10. METEORIACEAE

1. *Aerobryopsis longissima* (Dozy & Molk.) M. Fleisch.

2. *Floribundaria floribunda* (Dozy & Molk.) M. Fleisch.

11. MYURIACEAE

1. *Oedicladium pseudorufescens* (Hampe) B.C. Tan & Mohamed

12. NECKERACEAE

1. *Himantocladium plumula* (Nees) M. Fleisch.

2. *Neckeropsis fleischeri* (Dixon) Touw (Figure 1E)

12.3. *Pinnatella mucronata* (Bosch & Sande Lac.) M. Fleisch.

13. PILOTRICHACEAE

1. *Callicostella papillata* (Mont.) Mitt. *var. papillata*
2. *Callicostella papillata* (Mont.) Mitt. *var. prabaktiana* (Müll. Hal.) Streimann

14. POLYTRICHACEAE

1. *Pogonatum iwatsukii* Touw
2. *Pogonatum piliferum* (Dozy & Molk.) Touw
3. *Pogonatum rutteri* (Thér. & Dixon) Dixon
4. **Pogonatum subtortile* (Müll. Hal.) A. Jaeger

15. POTTIACEAE

1. *Barbula javanica* Dozy & Molk.

16. PTYCHOMNIACEAE

1. *Garovaglia angustifolia* Mitt.
2. *Garovaglia powellii* Mitt.

17. PYLAISIADELPHACEAE

1. **Clastobryum epiphyllum* (Renauld & Cardot) B.C. Tan & Touw
2. *Isopterygium albescens* (Hook.) A. Jaeger
3. *Mastopoma* sp.
4. *Taxithelium instratum* (Brid.) Broth.
5. *Taxithelium isocladum* (Bosch & Sande Lac.) Broth.
6. *Taxithelium planissimum* Broth.
7. *Trismegistia lancifolia* (Harv.) Broth.
8. *Wijkia* sp.1

18. RHIZOGONIACEAE

1. *Pyrrhobryum latifolium* (Bosch & Sande Lac.) Mitt. (Figure 1F)

19. SEMATOPHYLLACEAE

1. *Acanthorrhynchium papillatum* (Harv.) M. Fleisch.
2. *Acroporium adspersum* (Hampe) Broth.
3. *Acroporium convolutum* (Sande Lac.) M. Fleisch. (Figure 1A)
4. *Acroporium lamprophyllum* Mitt.
5. *Acroporium rigens* (Broth. ex Dixon) Dixon
6. *Clastobryophilum bogoricum* (Bosch & Sande Lac.) M. Fleisch.
7. *Papillidiopsis bruchii* (Dozy & Molk.) W.R. Buck & B.C. Tan
8. **Papillidiopsis malayana* (Dixon) B.C. Tan
9. **Papillidiopsis malesiana* W.R. Buck & B.C. Tan
10. *Papillidiopsis ramulina* (Thwaites & Mitt.) W.R. Buck & B.C. Tan
11. **Radulina hamata* (Dozy & Molk.) W.R. Buck & B.C. Tan var. *elegantissima* (M. Fleisch.) B.C. Tan, T.J. Kop. & D.H. Norris
12. *Radulina hamata* (Dozy & Molk.) W.R. Buck & B.C. Tan var. *hamata*
13. **Rhaphidostichum bunodicarpum* (Müll. Hal.) M. Fleisch.
14. *Sematophyllum* sp.
15. *Trichosteleum boschii* (Dozy & Molk.) A. Jaeger
16. *Trichosteleum mammosum* (Müll. Hal.) A. Jaeger
17. *Trichosteleum saproxylophilum* (Müll. Hal.) B.C. Tan, W.B. Schofield & H.P. Ramsay
18. *Trichosteleum stigmosum* Mitt.

20. SYMPHYODONTACEAE

1. *Chaetomitrium leptopoma* (Schwägr.) Bosch & Sande Lac.
2. *Chaetomitrium orthorrhynchum* (Dozy & Molk.) Bosch & Sande Lac.
3. *Chaetomitrium setosum* Broth. *ex* Dixon (Figure 1C)

21. THUIDIACEAE

1. *Thuidium pristocalyx* (Müll. Hal.) A. Jaeger var. *orientale* (Mitt. ex Dixon) Touw

MYCO-DIVERSITY OF THE HEART BORNEO (HoB) HINTERLAND: GERENAI-LONG MEKABA

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Abstract: Fungi are wildly diverse in appearance and perform different roles crucial to the forest ecosystem, including nutrient cycling, carbon stocking, soil, rain formation, food source for animals, habitat creation for many forest organisms, and ectomycorrhizal associations with plants. Sarawak's tropical forest is endowed with a tremendous diversity of fungi; however, their contributions to maintaining biodiversity and healthy forest ecosystems are often taken for granted. Hence, incessant documentation is required to obtain comprehensive myco-diversity data that could be essential in forest conservation and management. Appertaining to this, the 9th Heart of Borneo (HoB) Gerenai-Long Mekaba Scientific Expedition came timely to record pertinent information specifically within a logging area and its vicinity. A fungi survey was conducted along research transects within logged forest zones, patches of secondary forest due to agriculture clearing, and small areas of undisturbed forest. Totals of 120 fungi samples were collected, comprising 110 macrofungi and 10 cordyceps that are often called the "Zombie Fungi." Preliminary identification excluding the cordyceps has recorded 26 families and 52 Genus of mushrooms dominated by Polyporaceae and Polyporus respectively. Most samples (54%) were found inhabiting dead or rotten trees, roots, stumps, woods, branches, and twigs, while the rest were living on soil, debris, leaf litter, living roots, and lichen. Amongst the unique shapes of mushrooms recorded are polypore, gill, woody, earthstar, coral, jelly, cup, toothed, dead-man's finger, and puffball. All the fungi specimens are deposited in the Sarawak Fungarium for future reference.

Keywords: Scientific expedition, fungi diversity, mushroom, zombie-fungi, Sarawak Fungarium reference collections.

1 INTRODUCTION

The assessment of worldwide biodiversity patterns frequently disregards the viewpoint of fungi, as evidenced by the IPBES (2018). In Malaysia, the information on fungi is not extensive with poor understanding in Sabah and Sarawak (Lee *et al*., 2012). Sarawak is the biggest state in Malaysia, covering 12.4 million hectares (ha) of land area with 65% estimated to still be covered with forest (SFD, 2017). Located within the tropical region of Borneo Island, Sarawak is characterized by warm and humid climatic conditions that persist throughout the year. Schmit and Mueller (2007) suggest that the diversity of macro fungi species is expected to be greater in tropical regions than in temperate areas. Fungi are an essential component of thriving forest ecosystems as they engage in mutually beneficial relationships with plants, aid in the breakdown of organic matter, facilitate nutrient cycling, serve as a food source for a variety of forest- dwelling animals, and foster habitat diversity for numerous organisms found in the forest (Castellano *et al*., 2021). Therefore, it is imperative to incorporate the fungi diversity data into comprehensive management practices to ensure effective biodiversity conservation. Subsequently, the process of database development commences with the systematic documentation of fungi from vast habitats and their responses to the environment. In this regard, the 9th Heart of Borneo (HoB) Gerenai- Long Mekaba Scientific Expedition 2022 came in timely to provide invaluable findings on fungi diversity, particularly around one of the logged-over Permanent Forest Estate (PFE) areas in Sarawak.

1. Fungi overview

Gradual research has confirmed that fungi exhibit marked differences from plants due to their absence of cellulose and chlorophyll, which are crucial for processing carbon dioxide into sugars through the medium of sunlight (Peter & Shelly, 2011). Instead, fungi consist of microscopically thin, tubular hyphae that produce fruiting bodies after a period. Fungal fruiting bodies enable the sexual blending of two or more genetic types and produce spores for dispersal. Fungi can be classified into three categories consist of saprotrophic, pathogenic, and mutualistic (Allen *et al*, 2022). Saprotrophic species play a crucial role in recycling energy stored in organic matter through decomposition. Pathogenic species, on the other hand, can harm individual trees or other living organisms. Meanwhile, mutualistic species engage in symbiotic relationships with over ninety percent of the world's trees and flowering plant species (Pegler *et al*., 1992). Macro fungi or mushrooms are characterized by their significant morphological features of easily observed spore-bearing structures or fruit bodies (Kinge *et al*., 2020). According to Castellano *et al.* (2021), macro fungi are important agents for nutrient cycling by breaking down organic matter and fostering a diverse habitat for forest organisms. Moreover, around 1.5 million fungal species are entomopathogenic by colonizing the insect body, leading to further infection and onwards transmission (de Bekker *et al*., 2021). Known as “Zombie Fungi,” the host is hijacked behaviourally, exhibits heightened activity, and performs spore-dispersal body postures before death.

2. Documentation of fungi in Sarawak

The study of fungi diversity in Sarawak is being carried out within various vegetation types found in forested areas, aiming to document various species and their importance in maintaining a healthy ecosystem. Amongst the vegetation types in Sarawak are the Hill Mixed Dipterocarp Forest (7.35 mil. ha), Peat Swamp Forest (0.33 mil. ha), Mangrove Forest (0.07 mil. ha), and others such as the Kerangas Forest, Montane Forest, and Limestone Forest (Forest Department Sarawak Web, 2023). Appertaining to this, Sarawak Fungarium was established in 1976 by the Forest Pathology Unit of the Forest Department Sarawak with the primary goal of conducting research on planted plant diseases, particularly on *Acacia mangium* while also collecting macro fungi. In 2011, the Forest Pathology Unit was renamed the Mycology Programme, and since then, there has been a greater focus on documenting macro fungi samples. The Fungarium currently has a collection of more than 6,000 dried and wet specimens belonging to around 54 families and 108 genus. There are also other collections available, including the plant samples infected by fungal diseases, stained log samples caused by sap-stain fungi, and a few specimens from overseas. The oldest specimen recorded is the polyporus macro fungi known as *Pycnoporus sanguineus* that has been collected in 1954. Currently, the Sarawak's fungi database is being developed in a system called Forest Research Information System of Sarawak (FORISS), with a main focus on macro fungi records and reference collections.

3. HoB Gerenai-Long Mekaba Scientific Expedition 2022

Sarawak's rainforests are amongst the oldest in the world, with remarkable biodiversity being well conserved through the establishment of protected areas and sustainable production forest management. The Sarawak Heart of Borneo (HoB) area covers 50% (441,240 ha) of the Totally Protected Area (TPA) and 33 % (1,431,736 ha) of the total Permanent Forest Estate (PFE) in Sarawak. In addition, approximately 53% of PFE area in Sarawak is located within the HoB area. Subsequently, the HoB area is home to a vast diversity of flora and fauna with an abundance of endemic and unique species that need to be explored. Several scientific expeditions have been conducted in various locations, including Lanjak Entimau (2008), Batu Lawi (2009), Paya Maga (2010), Mentawai (2012), Long Banga (2016), Tama Abu (2017), Kelingkang (2019) and Gunung Pueh (2020). These scientific expeditions involved researchers of many scientific disciplines from local and international organizations in carrying out fieldwork and data collection. For the 9th HoB scientific expedition in 2022, Long Mekaba was selected as the location site. Long Mekaba is part of Gerenai Forest Management Unit (FMU), situated at Sg. Silat area, a tributary of the Baram River, in Miri Division, North-Eastern Sarawak. The Gerenai FMU shares boundaries with the Usun Apau National Park and Sg Moh Wildlife Sanctuary, forming a unique integration of forest landscapes. Its geological features range from flat riversides to low undulating hills and rugged mountainous terrain with altitude ranges from 150 to 1,820 meters a.s.l.

2 MATERIALS AND METHOD

The process of documenting fungi involves conducting field observation, recording data, collecting samples, processing samples, and updating the database. A Random sampling method was applied along eight (8) research transects comprised of Transect 1, 2, 5, 7, 9, 11, 12, and 16. The survey area covered logged-over lowland Dipterocarp Forest, patches of secondary forest due to agriculture clearing, Kerangas forest, and small zones of undisturbed forest that include three (3) main rivers consisting of Sungai Mekaba, Sungai Silat, and Sungai Sebua. The equipment used in the field were the Garmin GPS, light meter, camera, paper bag, bottle, zip-lock plastic bag, knife, field notebook, and pen. Along the research transect trails, observation was made on potential habitat or substrate of fungi such as dead, rotten, or decaying trees, logs, branches, twigs, stumps and roots, leaf litter, soil debris, living plants, and dead organisms such as insects. The information on forest type, coordinates, habitat, substrates, sample morphology, and obvious changes were recorded in the field notebook. Pictures of the fresh sample on its substratum were taken before being placed in the paper bag or bottle. Paper bags and bottles filled with 70% EtOH solution were used to keep dry and wet specimens. Preliminary identification (ID) was carried out at the base camp as soon as possi-ble by observing its conspicuous physical character using a hand lens and recording the description in ID forms (Gills or Non- Gills). Amongst the references being used for fungi ID are the Fungi Checklist of Malaysia, and online databases such as GBIF, Index of Fungi, and Mycobank. Some specimen needs to be cross-sectioned using a penknife to see the interior parts. Every sample was measured and labeled with specimen numbers. Each specimen was photographed again on dark coloured board with measurement and numbering labels. During the two - weeks expedition without sufficient electricity supply, dry specimens underwent sun drying while wet specimens remained in the 70% EtOH solution.

3 RESULTS AND DISCUSSION

A total of 120 fungi samples were collected, comprising of 110 macrofungi and the remaining 10 are the cordyceps or commonly called "Zombie fungi". All the specimens are being kept in the Sarawak Fungarium for future reference and re-ID by local or foreign experts.

1. Macrofungi

Preliminary ID of the samples excluding cordyceps, revealed 26 families and 52 genus of mushrooms. The most dominant family and genus were Polyporaceae and Polyporus respectively. Majority of the samples (22%) were found on dead or decaying trees, roots, stumps, branches, and twigs, while the rest were discovered on soil, debris, leaf litter, living roots, and lichen. The mushrooms exhibited unique shapes such as polypore, gill, woody, earthstar, coral, jelly, cup, toothed, dead man's finger, and puffball.

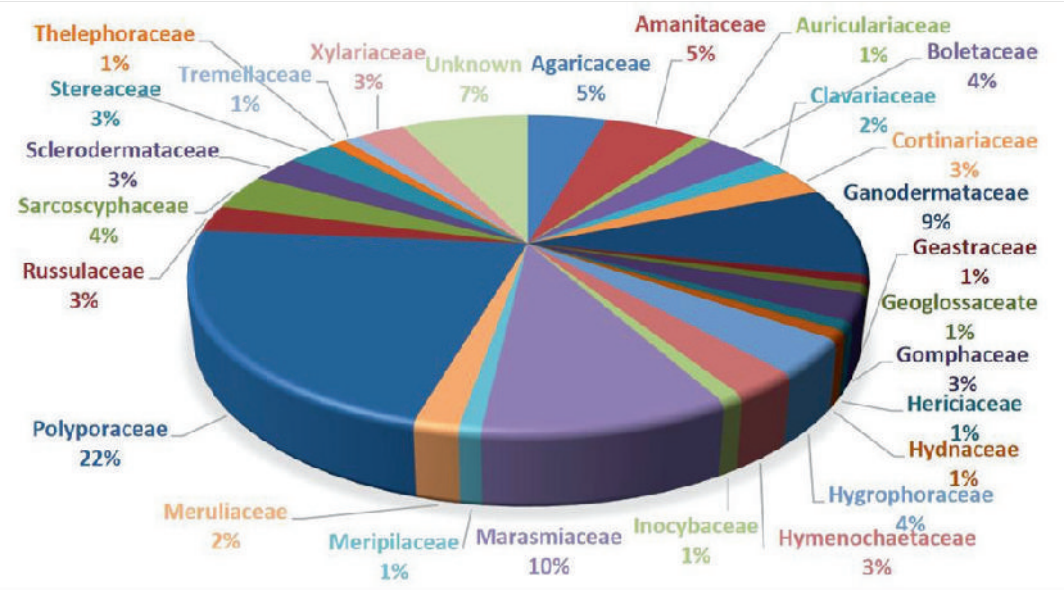


Figure 1: Macrofungi percentage by family.

Table 1: Family, genus/species, and substrates of macrofungi.

Family	Genus/Species	Substrates	No. of Sample
Agaricaceae	*Bovista* sp.	On leaf litter	1
	Calvatia sp.	On rotten branch	1
	Lycoperdon sp.	On rotten twig and soil	2
	Tulostoma sp.	On soil	2
Amanitaceae	*Amanita* sp.	On soil and leaf litter	5
	Amanita vaginata	On forest litter	1
Auriculariaceae	*Auricularia delicata*	On rotten branch	1
Boletaceae	*Boletus* sp.	On soil	3
	Heimioporus sp.	On leaf litter	1
Clavariaceae	*Clavulinopsis* sp.	On leaf litter	2
Cortinariaceae	*Cortinarius* sp.	On leaf litter, forest debris and soil	3
Ganodermataceae	*Amauroderma* sp.	On soil	4
	Ganoderma sp.	On dead/rotten tree and rotten root	4
	Ganoderma australe	On rotten wood and dead stump	2
Geastraceae	*Geastrum* sp.	On forest debris	1
Geoglossaceate	*Trichoglossum* sp.	On soil	1
Gomphaceae	*Clavaria* sp.	On soil and rotten tree	1
	Ramaria sp.	On soil	2
Hericiaceae	*Hericium* sp.	On rotten twig	1
Hydnaceae	*Hydnum* sp.	On lichen	1
Hygrophoraceae	*Hygrophorus* sp.	On forest debris, leaf litter and soil	4

Hymenochaetaceae	*Phellinus* sp.	On living tree and rotten tree and log	3
Inocybaceae	*Inocybe* sp.	On soil	1
Marasmiaceae	*Marasmiellus sp.*	On dead tree, rotten twig and bark of living tree	4
	Marasmius sp.	On leaf litter and rotten twig	5
	Trogia sp.	On leaf litter	1
	Unknown	On rotten twig	1
Meripilaceae	*Rigidoporus* sp.	On dead tree	1
Meruliaceae	*Cymatoderma* sp.	On rotten branch and rotten tree	2
Polyporaceae	*Coriolopsis* sp.	On rotten branch	1
	Earliella scabrosa	On rotten branch	1
	Favolus sp.	On rotten branch	1
	Lentinus sp.	On rotten wood	1
	Lignosus rhinocerus	On soil	1
	Microporus affinis	On rotten branch	3
	Microporus sp.	On rotten branch	1
	Microporus xanthopus	On rotten branch	2
	Panus sp.	On rotten branch	2
	Polyporus sp.	On dead and rotten tree, and rotten branch and twig	7
	Polyporus aqualarius	On rotten tree	1
	Pycnoporus sanguineous	On rotten tree	1
	Trametes sp.	On rotten tree	1
	Trichaptum sp.	On rotten tree	1
Russulaceae	*Lactarius* sp.	On soil	1
	Russula sp.	On soil	2

Sarcoscyphaceae	*Cookeina* sp.	On rotten branch and twig	2
	Cookeina tricholoma	On rotten branch	2
Sclerodermataceae	*Calostoma* sp.	On forest debris and leaf litter	2
Stereaceae	*Stereum* sp.	On dead tree and rotten branch	3
Thelephoraceae	*Thelephora* sp.	On soil	1
Tremellaceae	*Tramella* sp.	On rotten twig	1
Xylariaceae	*Xylaria* sp.	On rotten log and soil	2
	Xylaria polymorpha	On rotten branch	1
Unknown	Unknown	On forest debris, soil, leaf litter, living fine root and rotten tree branch and twig	8
		Total	110

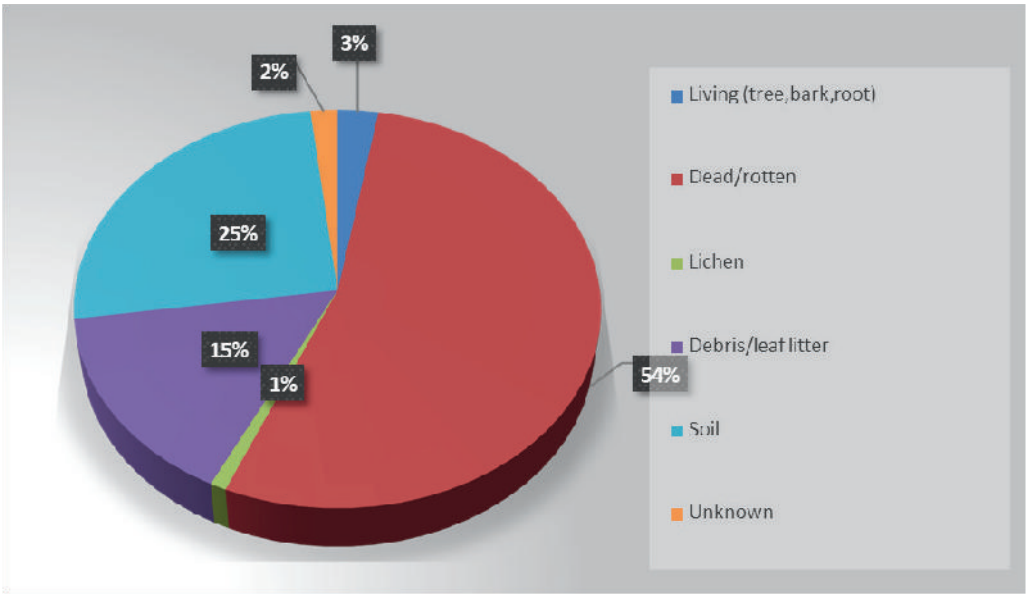


Figure 2: Macro fungi percentage by substrate

Table 2: Number of samples by substrate.

Substrate	No. of Sample
Living (tree, bark and root)	3
Dead/rotten (tree, log, branch, twig, wood and stump)	59
Lichen	1
Debris/leaf litter	17
Soil	28
Unknown	2
Total	110

Most of the samples (54%) inhabited dead or rotten trees, logs, branches, twigs, woods, and stumps. According to Lonsdale *et al.* (2008), wood-inhabiting fungi are key species that primarily responsible for wood decay in forest ecosystems hence, opening up the dead wood resource for other organisms. The second highest number of samples was recorded on soil (25%), while the rest were discovered on debris/leaf litter (15%), living tree, bark and root (3%), and lichen (1%). Meanwhile, another two (2) samples (2%) were found without substrate information.

Overall findings documented the presence of macro fungi that exhibit different characteristics, shapes, textures including woody, polyp ore, gilled, earthstar, cup, coral, puffball, jelly, toothed, and a few others. The distinctive morphologies of macro fungi facilitate their adaptation to a wide range of environmental conditions and ensure continuous reproduction.

Family: Ganodermataceae



Ganoderma australe



Ganoderma sp.

Family: Hymenochaetaceae



Phellinus sp.

Figure 3: Woody fungi

Woody fungi, also known as bracket or shelf fungi, are a type of fungi that have woody fruitbodies with pores or tubes on the underside. These fungi are primarily responsible for decomposing wood, making them important agents of wood decomposers. Additionally, some species of woody fungi that inhabit the soil form a mutualistic relationship with trees by forming mycorrhiza.

Family: Polyporaceae



Microporus xanthopus



Microporus affinis



Coriolopsis sp.

Figure 4: Polypore fungi

Polypore fungi, commonly referred to wood rotters, belong to the Polyporaceae family. These fungi typically produce bracket and shelf-shaped fruiting bodies that have a stalk. At the young stage, they are generally fleshy in texture but become hardened and leathery at maturity.

Family: Polyporaceae



Tuber of *Lignosus rhinoceros*

Figure 5: *Lignosus rhinocerus*

One of the valuable discoveries of polypore fungi is the *Lignosus rhinoceros*, also locally known as *Kulat Susu Harimau*. This rare species is believed to possess medicinal properties for treating various ailments such as cough, asthma, fever, gastritis, indigestion, and food poisoning. To prepare the remedy, the tuber, which resembles a root, is ground into a powder and boiled in water for consumption. According to folklore, the species was believed to grow on the spot where a tigress drips her milk while feeding her cubs, and this explains where the name comes from.

Family: Amanitaceae



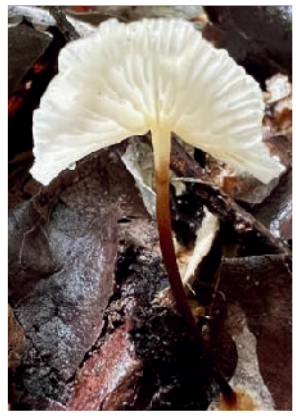
Amanita sp.

Family: Cortinariaceae



Cortinarius sp.

Family: Marasmiaceae



Marasmius sp.

Figure 6: Gilled fungi

Gilled fungi exhibit a wide range of sizes, colors, and shapes. These fungi consist of two primary components, a stem and a cap, with gills or lamellae on the underside that offer ample space for spore development. Depending on the species, gilled fungi may be fleshy, firm, soft, fragile, or even prone to deliquescing.

Family: Geastraceae



Geastrum sp.

Figure 7: Earthstar fungi

Earthstar fungi, together with puffballs and bird's nests, are categorized as gasteromycetes or "stomach fungi" due to their unique characteristic of producing spores inside their fruitbodies. Unlike other fungi that release spores into the air, gasteromycetes rely on raindrops to disperse their spores. Earthstar fungi particularly, are fascinating due to their exceptional appearance and dependence on raindrops to puff out their spores.

Family: Polyporaceae



Cookeina sulcipes *Cookeina tricholoma* *Cookeina* sp.

Figure 8: Cup fungi

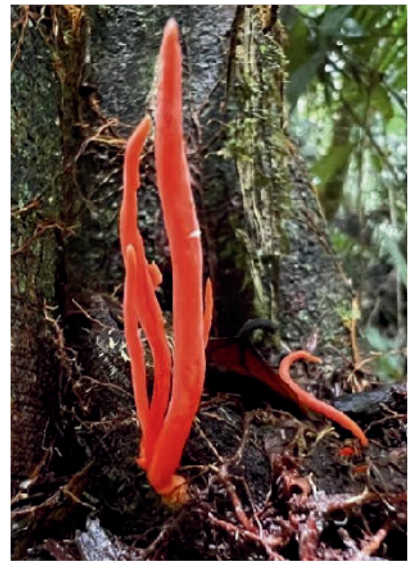
Cup fungi are usually found growing in small groups and are characterized by a distinct, deep cup-like shape that contains spores. The cup functions as a catcher for rainwater, which later will be absorbed by spore-containing cells causing it to swell up. As the cups dry out, the cells rupture, spreading the spores in the environment. This is an essential mechanism for the fungi to disperse their spores and reproduce.

Family: Gomphaceae



Ramaria sp.

Family: Clavariaceae



Clavulinopsis sp.

Figure 9: Coral fungi

Coral fungi, commonly referred to as clavarioid fungi or club fungi, are a type of fungi that form gelatinous fruitbodies that resemble elongated spindles or clubs, which may be either branched or unbranched. The spores of these fungi are produced on the surface of upright, simple, and branched basidiocarps, which add to their unique appearance.

Family: Agaricaceae



Bovista sp.



Lycoperdon sp.

Family: Sclerodermataceae



Calostoma sp.

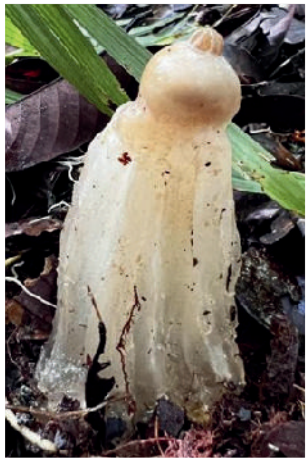
Figure 10: Puffball fungi

Puffball fungi are a variety of ectomycorrhizal fungi frequently found in association with trees. These fungi develop fruitbodies that hold a mass of spores that disperse upon the fruitbody's rupture. Interestingly, some species of puffball fungi have evolved to grow underground and rely on animals to disperse their spores.

Family: Sclerodermataceae



Calostoma sp.



Calostoma sp.

Family: Auriculariaceae



Auricularia delicata

Figure 11: Jelly fungi

Jelly fungi can be found commonly and are consumed as food in various types of cooking styles. These fungi possess gelatinous fruitbodies that aid in maintaining moisture and extending the spores' development. While some of them have a symbiotic relationship with the roots of trees, others are responsible for the decay of wood or act as parasites.











Figure 12: Other types of fungi

3.2 Cordyceps

In the Gerenai-Long Mekaba area, a total of 10 samples of cordyceps or zombie fungi were recorded during the expedition. These fungi are entomopathogens that hijack insect behaviour, causing their hosts to exhibit heightened activity, seek out elevated positions, and display body postures that promote sexual spore-producing structures elevated by a conspicuous stalk.

Cordyceps samples on insects from family Bespidae.



Cordyceps samples on insects from family Sphecidae.



Cordyceps samples on insects from few other family.



Figure 13: Zombie fungi in Gerenai-Long Mekaba area.

According to Tang *et al*., (2023), there are approximately 750 types of Cordyceps found across the globe, with habitats in South Asia, Europe, and North America. However, only 35 of these Cordyceps species have been recognized for their medicinal purposes in traditional medicine, and have been distinguished based on their diverse bioactive components (Olatunji *et al*., 2018). In recent times, the cordyceps fungi gained significant popularity as a source of various healthcare products such as health supplements, cough syrup, coffee powder, etc. The use of cordyceps fungi in healthcare products has been widely acknowledged and appreciated by health enthusiasts worldwide. Despite their importance, this group of beneficial fungal pathogens still poorly documented regarding their diversity, ecology, and evolutionary relationships.

4 CONCLUSION AND RECOMMENDATION

Intensive and continuous documentation on fungi diversity is crucial to obtain extensive data for comprehensive biodiversity conservation efforts in Sarawak's tropical forest, particularly within PFE areas. Additionally, the data offer valuable references for conducting applied research and facilitating effective forest management to preserve the natural environment for the benefit of future generations.

As edible mushroom is commonly taken for food, it is important to be more cautious when selecting wild mushrooms for consumption. Misidentifying toxic mushrooms as edible ones may cause serious consequences; therefore, it is best to be knowledgeable about the different types of mushrooms before consuming them. Furthermore, the fascinating presence of macro fungi with their diverse features and colors in Gerenai and Long Mekaba could potentially become a significant eco-tourism attraction within the HoB area.

Studies have revealed that the interaction between fungi and insects in natural forests can lead to the production of bioactive compounds with potential health benefits. These compounds have been utilized in traditional medicine and are now being explored for modern health treatments. Further investigation on the diversity of cordyceps, as well as their environmental and ecological factors is vital to aid research on these valuable fungi into high-quality therapeutic applications.

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I would like to extend my gratitude to colleagues from the Research and Development Division (Mycology and Entomology team members), International Affairs Division (Heart of Borneo (HoB) Sarawak), and other Divisions and Regional Forest Offices of Forest Department Sarawak for their great commitment during the scientific expedition. My special thanks to the local people of Long Mekaba village and Gerenai FMU for their warm welcome and immense assistance; the paramedic team of the Malaysia Armed Forces for their good healthcare services; and all participants from other agencies for their boundless moral support. In this opportunity, I would like to acknowledge the late Mr. Mohd. Shahbudin Sabki for his invaluable contributions to the HoB Sarawak project especially during the preparation of the *RMKe*-12 budget.

GINGERS OF GERENAI – LONG MEKABA

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Abstract: Ginger species are a diverse group of rhizomatous, aromatic perennial herbs with the centre of diversity in Southeast Asia. The Zingiberaceae diversity in the Gerenai – Long Mekaba HoB area, Sarawak, is documented in this paper. A total of 57 taxa from 17 genera (including non-native species) of gingers were recorded from the Gerenai – Long Mekaba areas. *Etlingera*, *Zingiber* and *Alpinia* are the most specious genera recorded with 10, 8 and 6 species respectively. The diversity of gingers recorded from the Gerenai – Long Mekaba is considered high. The number, however, is predicted to be higher as the exploration only covered a small fragment of the Gerenai FMU and the limitation of collection days.

Keywords: diversity, Gerenai – Long Mekaba Scientific Expedition 2022, Gerenai FMU, Zingiberaceae

1 INTRODUCTION

The gingers, belonging to the family Zingiberaceae are rhizomatous, perennial herbs which are aromatic in any or all plant parts. The Zingiberaceae comprises 53 genera and more than 1200 species worldwide with its centre of diversity in Southeast Asia. Malaysia harbours almost 40% of the world's genera and close to 30% of the world's taxa (Ibrahim et al., 2011). Of these, 21 genera and about 200 species were reported from Sarawak (Meekiong & Teo, 2022; Meekiong et al., 2021), and the exact number has not been established as more work is needed.

The gingers are diverse in their habitats, with mostly terrestrial, lithophyte, and rheophyte and a few with the epiphytic habit (Lamb et al., 2013; Poulsen, 2006). For instance, Alpinia epiphytica Meekiong, Ipor & Tawan, is the only species in the genus with the epiphytic habit (Meekiong et al., 2011). The gingers are also diverse in habitat, thriving in the shaded forest, from mangrove to mixed dipterocarp forest, kerangas, riverine, limestone, and up to montane forest at 2000 m altitude.

The ginger classification used in this report follows the latest taxonomical review by de Boer et al. (2018) and Poulsen et al. (2018).

2 MATERIALS AND METHODS

Sites

Field surveys were conducted in the Gerenai Forest Management Unit (FMU) areas, specifically within the Long Mekaba areas.

Materials and Methods

Only fertile samples of gingers (bearing flowers or fruits or both) were collected as voucher specimens. The collection process followed standard methods as suggested by Bridson and Forman (1992). The voucher specimens were used for identification and verification, conducted at the Herbarium of Forest Department Sarawak (SAR).

3 RESULTS AND DISCUSSIONS

A total of 57 taxa from 17 genera were recorded from the Gerenai FMU areas (including non-native species from Long Mekaba village). All the species in the genus *Curcuma* and *Kaempferia* and three other species (*Alpinia galanga, Zingiber officinale* and *Z. ottensii*) are non-native plants that were planted in the orchards for spices, medicinal or sacramental purposes. *Etlingera, Zingiber and Alpinia* were the most specious genus with 10, 8 and 6 species respectively (Figure 1). Most of the *Etlingera* species recorded were dominated in open spaces of secondary forest and large forest gaps and by the roadside of the logging road. For example, *E. coccinea* and *E. brevilabrum* were found commonly and abundantly on the roadsides of logging roads.

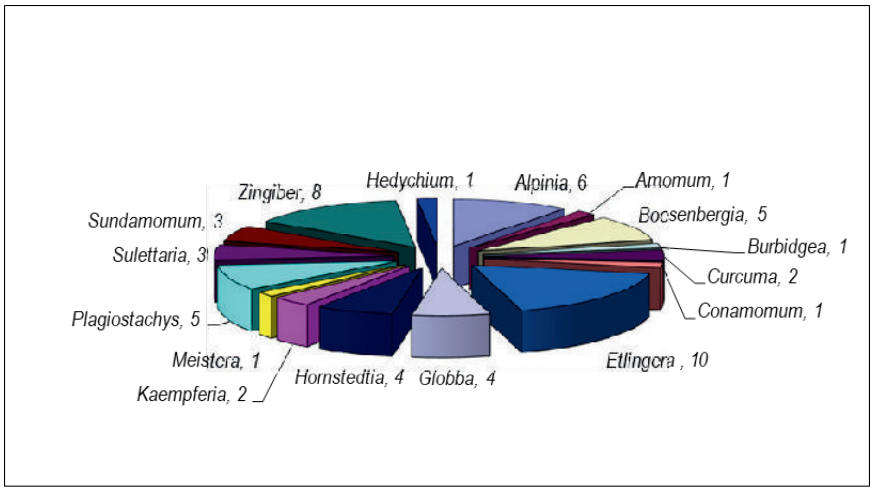


Figure 1: Zingiberaceae diversity (by genus) in Gerenai, FMU

One of the remarkable findings during this expedition was the discovery of *Boesenbergia ornata* (N.E. Br.) R.M. Sm. (a second location for Sarawak). This species was discovered and described from Kalimantan, Indonesia in the year 1884 under the name of *Kaempferia ornata* N.E. Br., and since then never been collected. An intensive survey has been conducted by the first author since 2008 throughout Sarawak to document the plants in the order Zingiberales. In 2017, during the fieldwork in Mukah division, he discovered a unique *Boesenbergia* species. A species with beautiful foliage with a metallic silver band on the midrib, purple underneath and striking orange flowers. The species was verified via matching the type species deposited at Kew (*http://specimens.kew.org/herbarium/K000255372*) and notes from Smith (1980), confirming that the species was *Boesenbergia ornata,* which is a long-lost mysterious *Boesenbergia* from Borneo.

Table 1: Comparison of the number of gingers species recorded from the Heart of Borneo Scientific Expeditions (2008 – 2022) and total number projection for Sarawak.

Genus/Locality	No. of species recorded							
	Gerenai FMU	LEWS	Payeh Maga	Mentawai (incl. Camp 5)	Long Banga	Tama Abu	Pueh FR	Sarawak[e]
Alpinia	6	7	6	4	7	5	4	13
Amomum	1	1	2	3	3	2	1	8
Boesenbergia	5	11	3	17	-	3	2	35
Borneocola	-	4	-	-	-	-	3	25
Burbidgea	1	3	4	2	-	1	1	5
Camptandra	-	-	1	1	-	-	1	1
Conamomum	1	1	1	1	1	-	1	2
*Curcuma**	2	-	-	1	-	-	3	4
Epiamomum	-	1	-	2	1	-	-	3
Etlingera	10	11	13	10	10	12	8	28
Globba	4	8	5	7	8	5	3	10
Geocharis	-	1	-	1	-	-	-	2
Geostachys	-	-	1	-	1	-	-	1
Haniffia[a]	-	-	-	-	-	-	-	1
Haplochorema[b]	-	2	-	-	-	-	-	4

Hedychium	1	2	4	3	2	1	-	5
Hornstedtia	4	6	6	6	5	5	5	10
*Kaempferia**	2	-	-	-	-	-	2	2
Meistera	-	1	2	2	-	1	1	2
Myxochlamys[c]	-	-	-	-	-	-	-	1
Plagiostachys	5	7	4	5	7	4	3	10
Scaphochlamys	-	1	-	-	-	-	3	3
Sulettaria	3	3	5	4	4	4	1	8
Sundamomum	3	5	5	7	10	6	2	15
Tamijia[d]	-	-	-	-	-	-	-	2
Zingiber	8	5	5	7	6	5	5	14
TOTAL	**57**	**80**	**65**	**83**	**64**	**54**	**49**	**214**

*Not native

[a] representing by a single species – Haniffia santubongensis (currently recorded only from the type locality: Gunung Santubong National Park)

[b] sunken into the genus *Boesenbergia* (Mood et al.)

[c] this genus was described from Kalimantan, yet to be recorded in Sarawak

[d] so far not recorded in the HoB area; distribution more on coastal northeastern Sarawak and also in Brunei Darussalam

[e] Total number projection for Sarawak

Data extracted from Ibrahim et al. (2011), Meekiong et al. (2021), Meekiong & Teo (2022), Sakai & Nagamasu (2000a, 2000b) and Smith (1985, 1986, 1987, 1988, 1989)

The number of gingers recorded from the Heart of Borneo Scientific Expedition areas from the year 2008 until the recent, Gerenai – Long Mekaba (2022) has been compared (Table 1). Overall, all the HoB scientific expedition areas are considered rich with ginger species, with Mentawai (including Camp 5 of Mulu National Park) is the highest with 83 species, followed by the Lanjak Entimau Wildlife Sanctuary (LEWS) and Payeh Maga with 80 and 65 species respectively. Meanwhile, Pueh FR (excluding the Pueh National Park) was recorded with only 49 species, the lowest among the areas.

Observations made during the studies revealed that ginger commonly dominated disturbed areas, such as secondary forests, roadsides of logging roads and a large gap in forested areas. The species of *Etlingera* (e.g. *E. baramensis, E. brevilabrum, E. coccinea, E. elatior, E. fimbriobracteata, E. foetens, E. metriochielos, E. nasuta*), *Hornstedtia* (*H. reticulata* and *H. scyphifera*) and *Plagiostachys crocydocalyx* are the common species recorded in the disturbed open spaced areas in the lowland forests. Whereas *Burbidgea schizochiela* and *Etlingera barioensis* are common at higher altitudes (≥ 1000 m a.s.l). Other species are tending to grow on shady under the canopy, especially in wet areas near streams or riverbanks and gullies. A few species are very rare and found specifically in their niche (hyperendemic). For example, many *Boesenbergia* species (i.e. *B. armeniaca, B. cordata, B. flavorubra, B. grandis, B. hutchinsonii* and *B. kerbyi*) are endemic to the limestone habitat of Mulu National Park.

4 CONCLUSION

The diversity of gingers at Gerenai FMU is considered high with 55 species from 16 genera recorded. The number of ginger species reported herein surely will be increasing as many areas are yet to be explored. Therefore, further study is strongly recommended to clearly understand the diversity of gingers from the Gerenai FMU.

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A list of Gingers from Gerenai FMU

Alpinia Roxb.
- *A. beamanii* R.M. Sm.
- *A. galanga* (L.) Willd. *
- *A. glabra* Ridl. var. *glabra*
- *A. havilandii* K. Schum.
- *A. ligulata* K. Schum.
- *A. nieuwenhuizii* Val.

Amomum Roxb.
- *A. kerbyi* (R.M. Sm.) Skornick & Hlavata

Boesenbergia Kuntze
- *B. flavoalba* R.M. Sm.
- *B. oligosperma* (K. Schum.) R.M. Sm.
- *B. ornata* N.E. Br.**
- *B. pulchella* (Ridl.) Merr.
- *B. variegata* R.M. Sm.

Burbidgea Hook. *f.*
- *B. stenantha* Ridl.

**Curcuma* L.
- *C. longa* L.*
- *C. zanthorrhiza* Roxb. *

Conamomum Ridl.
- *C. xanthophlebium* (Baker) Skornick & A.D. Poulsen

Etlingera Giseke
- *E. baramensis* S. Sakai & Nagam.
- *E. barioensis* A.D. Poulsen
- *E. burttii* R.M. Sm.
- *E. brevilabrum* R.M. Sm.
- *E. coccinea* (Bl.) S. Sakai & Nagam.
- *E. elatior* (Jack) R.M. Sm.
- *E. metriocheilos* (Griff.) R.M. Sm.
- *E. nasuta* (K. Schum.) R.M. Sm.
- *E. rubromarginata* A.D. Poulsen & Mood
- *E. velutina* (Ridl.) R.M. Sm.

Globba L.
- *G. atrosanguinea* Teijsm. & Binn.
- *G. brachyanthera* K. Schum.
- *G. muluensis*
- *G. tricolor* Ridl.

Hornstedtia Retz.
- *H. havilandii* (K. Schum.) K. Schum.
- *H. incana* R.M. Sm.
- *H. reticulata* (K. Schum.) K. Schum.
- *H. scyphifera* (J. Koenig) Steud.

**Kaempferia* L.
K. galanga L.*
K. pulchra Ridl.*

Meistera Giseke
M. gyrolophos (R.M. Sm.) Skornick & M.F. Newman

Plagiostachys Ridl.
P. albiflora Ridl.
P. crocydocalyx (K. Schum.) B.L. Burtt & R.M. Sm.
P. breviramosa Cowley
P. roseiflora Julius & A. Takano
P. strobilfera (Baker) Ridl.

Sulettaria A.D. Poulsen & Mathisen
S. anomala (R.M. Sm.) A.D. Poulsen & Mathisen
S. surculosa (K. Schum.) A.D. Poulsen & Mathisen
Sulettaria sp.3

Sundamomum A.D. Poulsen & M.F. Newman
S. borealiborneense (I.M. Turner) A.D. Poulsen & M.F. Newman
S. dictyocoleum (K. Schum.) A.D. Poulsen & M.F. Newman
S. longipedunculatum (R.M. Sm.) A.D. Poulsen & M.F. Newman

Zingiber
Z. colaratum N.E. Br.
Z. flammeum Theilade & Mood
Z. griffithii Baker
Z. longipedunculatum Ridl.
Z. martinii R.M. Sm.
Z. officinale Roscoe*
Z. ottensi Valeton*
Z. pachysiphon B.L. Burtt & R.M. Sm.

**non-native, cultivated*

ETHNOBIOLOGICAL RESEARCH STUDY WITH KENYAH COMMUNITY AT LONG MEKABAR, GERENAI CAMP, SARAWAK

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Abstract: Useful plants have continued to be the most affordable and easily accessible source for the daily consumption of local communities. The data was collected from knowledgeable locals using guided field walks. The aim of this research was to record the traditional knowledge of beneficial plant species utilized by the Kenyan community in Long Mekabar, Gerenai Camp, Sarawak. Additionally, the study sought to identify the most frequently used plant by the Kenyan community of Long Mekabar, Gerenai Camp, Sarawak. Twenty-seven (27) useful plants were identified, representing eighteen (18) families. Piperaceae with four (4) species was the most common family, followed by Annonaceae and Zingiberaceae (three (3) species each), Lauraceae and Meliaceae (two (2) species each), and other families (one (1) species each). The majority of useful plants, four (4) species, were used to remove intestinal gas and as a repellent, while three (3) species of useful plants were used to remove intestinal gas alone. For medicinal purposes, leaves were the most commonly used plant parts for remedy preparation, whereas crushing was the most frequently stated herbal remedy preparation method. Notably, herbal remedies were administered orally for the treatment of ailments. All of the useful plants were collected from the wild. The documented indigenous practices on useful plants can provide scientific baseline data for future research and development studies.

Keywords: Borneo, community, Kenyah, Traditional knowledge

1 INTRODUCTION

Sarawak stands out as one of the world's biodiverse regions, housing over 40 sub-ethnic groups, each possessing its own unique culture, language, and way of life. This rich diversity has given rise to numerous distinctive ethnobotanical systems. However, the swift pace of urbanization poses a significant threat to this traditional knowledge, placing it at risk of extinction. Despite the widespread availability of modern medicine, certain Sarawakian villages still practice traditional medicine, as noted by Ripen and Noweg (2016). However, this knowledge is primarily retained by village elders, given that many young individuals migrate to urban areas in pursuit of better employment opportunities (Christensen, 2002).

A notable observation by Rajoo in 2022 is the scarcity of ethnobotanical studies focusing on the Kenyah community in Sarawak. This gap in research suggests a genuine risk of losing invaluable traditional knowledge if immediate preservation measures are not implemented. Hence, the motivation behind this study was to document and preserve the traditional knowledge of the Kenyah community in Long Mekabar, Gerenai Camp.

2 MATERIALS AND METHODS

1. Study Site

The research engaged the Kenyah communities specifically in Long Mekabar, Gerenai Camp. Prior to the commencement of the study, securing informed consent from the local community was a critical step in documenting traditional knowledge of beneficial plants, in line with Part V of the Sarawak Biodiversity Regulation, 2016. The prior informed consent from communities were obtained on 11 March 2023. The permission to conduct research on biological resources was obtained from state with the permit number of SFC.810-4/6/1 (2023)-042 and the letter from Sarawak State Secretary with the reference number of JKM/SUK/100-1/5 Vol. 5 (22). The data collection process was bifurcated into two phases; the first phase focused on the collection of ethnobotanical information, while the subsequent phase involved data analysis.

2. Documentation, plant collection and specimen's identification

The first phase of data collection is the ethnobotanical data, which includes use of plant documentation and plant collection. The documentation included:

- Usage and plant preparation
- Local name, botanical description, location and habitat
- Scientific name
- Photo of the plants
- GPS coordination

The plant collection included:

The plant samples were collected and brought back to SBC for R&D analysis and herbarium specimens. The herbarium samples were brought to Sarawak Herbarium (SAR) for the identification process.

2.3 Data Analysis

The second phase is data analysis of ethnobotanical data, which includes the useful plant species that were mostly used by the Kenyah Community of Long Mekaba, Gerenai Camp. The data was compiled into Excel and the pie chart/graph was generated.

3 RESULTS AND DISCUSSION

Twenty-seven useful plants documented and collected belonged to eighteen families. Piperaceae with four species was the most common family, followed by Annonaceae and Zingiberaceae (three species each), Lauraceae and Meliaceae (two species each), and other families (one species each). Abu et al. (2023), documented Rubiaceae, Piperaceae, Leguminosae, Lamiaceae, Annonaceae, and Zingiberaceae as the most prominent therapeutic plant families by local ethnic groups. (Table 1)

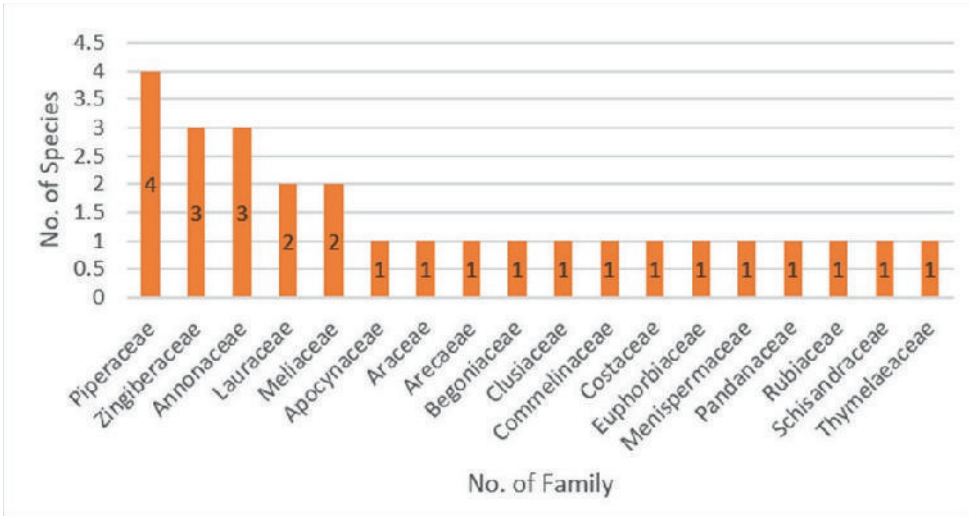


Figure 1: Documented families of useful plants

Table 1: List of documented and collected useful plants.

No	SBC	Family	Genus	Species	Local name	Usage
1	16721	Meliaceae	*Aglaia*	*faveolata*	Kayo	Building material
2	16722	Araceae	*Homalomena*	*rostrata*	Long Bala	1. Antiseptic 2. Antidote 3. Reducing high blood pressure and managing diabetes 4. Dog stimulant
3	16723	Rubiaceae	*Nauclea*	sp.	Kayo Bao	Remove intestinal gas
4	16724	Piperaceae	*Piper*	*porphyrophyllum*	Daun rimo	To treat bruises on skin
5	16725	Annonaceae	Goniothalamus	macrophyllus	Timang	1. Remove intestinal gas 2. Ritual 3. Repellent
6	16726	Annonaceae	*Polyalthia*	sp.	Kayo wangi	1. Remove intestinal gas 2. Ritual 3. Repellent
7	16727	Lauraceae	*Cinnamomum*	sp.	A'net Ba'o	1. Remove intestinal gas 2. Ritual 3. Repellent
8	16728	Euphorbiaceae	*Trigonopleura*	*malayana*	Kelalai	Energy booster
9	16729	Annonaceae	*Goniothalamus*	*velutinus*	Timang	1. Remove intestinal gas 2. Ritual 3. Repellent
10	16730	Meliaceae	*Aglaia*	*lancifolia*	Kamlembun yau	Remove intestinal gas
11	16731	Thymelaeaceae	*Aquilaria*	*microcarpa*	Gaharu	1. Fever 2. Ritual 3. Energy booster
12	16732	Costaceae	*Paracostus*	sp.	Kesua	Ornamental

13	16733	Pandanaceae	*Freycinetia*	sp.	Akar da'an	Backache
14	16734	Schisandraceae	*Kadsura*	*borneensis*	Akar brunai	1. Skin care (mask) 2. Rope
15	16735	Piperaceae	*Piper*	*vestitum*	Tong burung	Food flavouring
16	16736	Piperaceae	*Piper*	sp.	Tepila'	Food flavouring
17	16737	Commelinacea e	*Commelina*	sp.	Lanau	Vegetable
18	16738	Zingiberaceae	*Plagiostachy s*	*breviramosa*	Ti'tek	Remove intestinal gas
19	16739	Zingiberaceae	*Etlingera*	*rubumarginata*	Tepo'	Food flavouring
20	16740	Piperaceae	*Piper*	sp.	Akar koyok	Remove intestinal gas
21	16741	Menispermace ae	*Fibraurea*	sp.	Akar tuai	1. Antiseptic 2. Energy booster
22	16742	Lauraceae	*Litsea*	*cubeba*	Belang'lah	1. Eczema 2. Remove intestinal gas
23	16743	Apocynaceae	*Alstonia*	sp.	Jelutong pulut	1. To treat sprain 2. Antiseptic
24	16744	Arecaeae	*Eugeissona*	*utilis*	Nanga	Diabetes
25	16745	Zingiberaceae	UNID-seedling		Keburu	Antidote
26	16746	Clusiaceae	*Garcinia*	*beccarii*	Adew	Cholesterol, slimming and diabetes
27	16747	Begoniaceae	*Begonia*	sp.	Hilang bato'	Food flavouring

Pattern of Utilization

A total of twenty-seven useful plant species, employed to address fourteen different ailments, were documented. These plants were primarily utilized for two main purposes: removing intestinal gas and acting as a repellent (involving four species), and solely for removing intestinal gas (involving three plant species). According to Abu et al. (2023), the diverse use of 166 therapeutic plants by local ethnic groups, focusing on treating gastrointestinal and cardiovascular issues.

In medicinal practices, leaves emerged as the most commonly used plant parts for preparing remedies, with crushing identified as the predominant method for herbal remedy preparation.

Notably, oral administration was the prevalent mode of delivering herbal remedies for ailment treatment. It is noteworthy that all the beneficial plants were sourced from the wild.

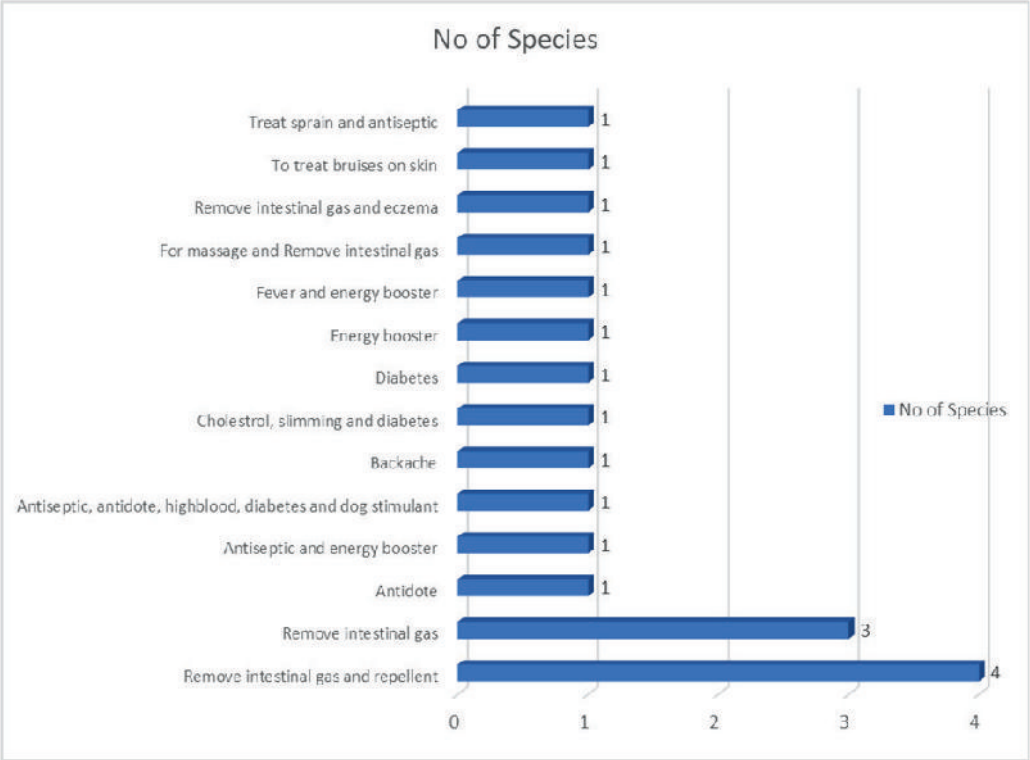


Figure 2: Utilization pattern of documented useful plants

In summary, the study documented twenty-seven plant species with diverse uses for treating fourteen ailments. The predominant applications included removing intestinal gas and serving as a repellent. Leaves were frequently utilized for remedy preparation, and the common method involved crushing. Oral administration of herbal remedies was the prevailing practice. Most importantly, all the useful plants were gathered from the wild.

4 CONCLUSION

Although the communities in the Long Mekabar and Gerenai Camp areas are connected to modern medical facilities and medicines, some of them still use plants occasionally since they know their uses, and this cost them less as compared to conventional medicine. The study shows that the Kenyan community in Long Mekabar, Gerenai Camp is still rich in traditional knowledge of useful plants.

The documentation of plants used by the Kenyan community in Long Mekabar, Gerenai Camp, will provide practical recommendations to researchers and communities to support the sustainable use of plant resources and the preservation of traditional knowledge. This study can provide scientific baseline data for future research and development studies.

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ODONATA FAUNA OF LONG MEKABA, SARAWAK

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Abstract: Dragonflies and damselflies are a group of aquatic insects in the order Odonata. They form an important biotic component in fresh water aquatic ecosystem, and they can be used as a bio-indicator for fresh water quality and health of aquatic ecosystem. The Odonata fauna of Long Mekaba was surveyed during the Gerenai-Long Mekaba HoB Scientific Expedition on 12-25 September 2022. Field observation and sampling of adult Odonata were conducted at various aquatic habitats at Long Mekaba area within the Gerenai FMU. A total of 62 species in 12 families were recorded during the scientific expedition – 25 species in family Libellulidae, nine species in family Platycnemididae, six species in family Coenagrionidae, five species in family Calopterygidae, three species each in families Platystictidae, Euphaeidae and Aeshnidae, two species each in families Chlorocyphidae, Devadattidae and Gomphidae, and one species each in families Macromiidae and Synthemistidae. Of the species recorded, nine species are new records for Gerenai FMU – *Vestalis atropha, Libellago semiopaca, Onychargia atrocyana, Ischnura senegalensis, Indaeschna grubaueri, Diplacodes trivialis, Lyriothemis biappendiculata, Orchithemis pulcherrima* and *Pantala flavescens*. With the published records from previous surveys, 94 Odonata species have been known to occur in Gerenai FMU. This represents 25% of the species of Sarawak. It is also worth to note that 18 species recorded at Long Mekaba area during the scientific expedition are endemic to Borneo. These endemic species are of conservational value. Therefore, the Long Mekaba area, as well as the Gerenai FMU, is generally rich in Odonata fauna, indicating the good health of the aquatic ecosystem at Long Mekaba area.

Keywords: Biodiversity, Borneo, damselflies, dragonflies, Generai FMU

1 INTRODUCTION

Dragonflies and damselflies are a group of aesthetic insects in the order Odonata and are easily recognised by a pair of large compound eyes, short antennae, two pairs of membranous net-veined wings and a slender body. They are one of the important biotic components in freshwater aquatic ecosystem, and they can be used as a good bio-indicator for freshwater quality and health of aquatic ecosystem. More than 6000 species of Odonata are distributed throughout the world (Dijkstra *et al*., 2013). Malaysia has more than 400 species (Furtado, 2021) while Borneo has more than 370 species (Dow *et al*., 2022). Within the regions in Borneo, the Odonata of Sarawak is quite well-studied with more than 310 species being recorded in the state (Dow *et al*., 2022).

Long Mekaba is situated at Batang Baram-Sg. Silat area and within Gerenai Forest Management Unit (FMU) in Miri Division. The Gerenai FMU shares border with Usun Apau National Park and Sg. Moh Wildlife Sanctuary. Dow (2020) conducted Odonata surveys at Gerenai FMU in July 2014 and February 2020. Some of the sampling locations in the surveys were excluded as the sites within Gerenai FMU due to misinformation (Dow per. com.). With the rectification of the misinformation of sites, a total of 85 species were recorded for Gerenai FMU from the surveys (Dow, 2020; Dow *et al*., 2021). Forest Department Sarawak organised the Gerenai-Long Mekaba HoB Scientific Expedition on 12-25 September 2022 as part of the Heart of Borneo (HoB) initiative. The biodiversity of Odonata from Long Mekaba area was studied during the scientific expedition. The study was intended to generate more Odonata data for Gerenai FMU. The data obtained from this study is of much use for strategic management plan of Generai FMU.

2 METHODOLOGY

The Odonata sampling was carried out during the Gerenai-Long Mekaba HoB Scientific Expedition on 12-25 September 2022. Field observation and sampling of adult Odonata were conducted at various aquatic habitats at Long Mekaba area within the Gerenai FMU (Table 1; Figures 1 & 2). Most of these aquatic habitats are located along the trails established by the expedition organiser. A hand-held net was used to catch adult insects. The caught specimens were then treated with acetone and dried with silica gel. Photographs of Odonata were also taken where possible for records. A few specimens were taken as voucher specimens. The voucher specimens are kept in Forest Department Sarawak and Centre for Insect Systematics, Universiti Kebangsaan Malaysia for reference. Identification of specimens down to species was done based on relevant references and specimens in collection.

Table 1: Description of sampling locations in the Long Mekaba area.

Location	Description
A	Expedition campsite by Sg. Mekabar; ponds and river; N2°54'45.2", E114°55'45.7"; 219 m.
B	Mekabar River (including trails 11, 12, 13 and 14), mainly along Sg. Mekabar; rivers, streams and streamlets; N2°54'29.0", E114°55'28.9"; 258 m.
C	Trail 16 (including Long Mekaba village); streams, streamlets and ponds; N2°54'27.0", E114°56'29.6"; 195 m.
D	Trails 7 and 8; streams and streamlets; N2°55'38.3", E114°55'44.1"; 546 m.
E	Trail 9; streams and streamlets; N2°54'46.3", E114°55'38.9"; 262 m.
F	Trail 1; streamlets and ponds; N2°55'8.1", E114°59'9.8"; 385 m.
G	A section Sg. Sebua near Trail 1; river and ponds; N2°55'32.4", E114°59'17.0"; 321m.
H	Trail 5; Sg. Sebua; river and streams; N2°56'41.6", E114°57'35.1"; 222 m.

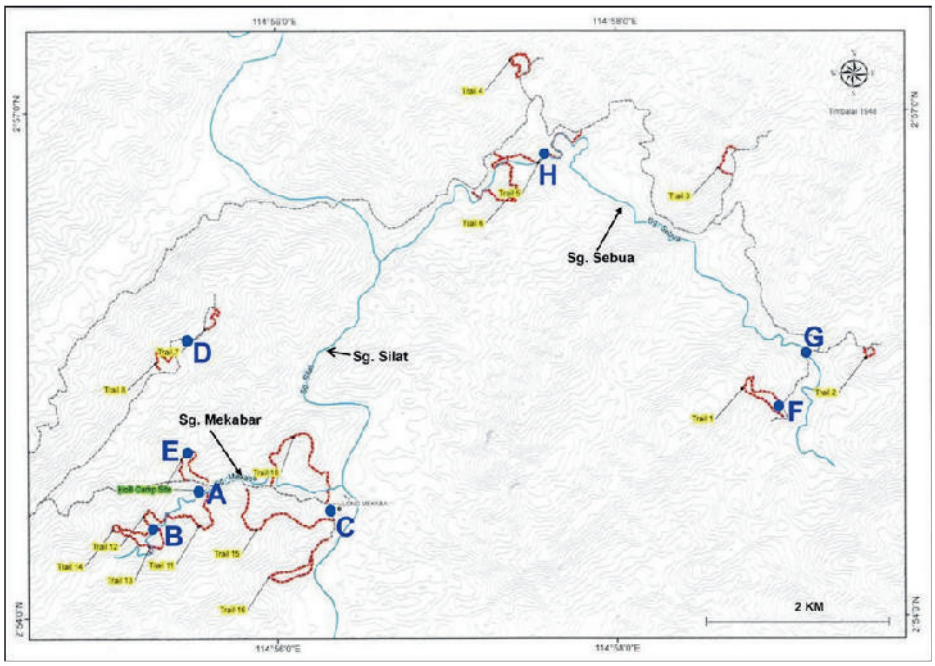


Figure 1. Sampling locations at Long Mekaba area. See Table 1 for details of the locations.



Figure 2. Some aquatic habitats at the Long Mekaba area. A: a pond at location A, B: Sg. Mekaba at location B, C: a streamlet at location D, and D: Sg. Sebua at location G.

3 RESULTS AND DISCUSSION

A total of 62 Odonata species in 12 families were recorded during the scientific expedition – 25 species in family Libellulidae, nine species in family Platycnemididae, six species in family Coenagrionidae, five species in family Calopterygidae, three species each in families Platystictidae, Euphaeidae and Aeshnidae, two species each in families Chlorocyphidae, Devadattidae and Gomphidae, and one species each in families Macromiidae and Synthemistidae (Table 2). Photographs of some of the species taken at Long Mekaba area are shown in Figure 3. Of the species recorded, nine species are new records for Gerenai FMU – *Vestalis atropha*, *Libellago semiopaca*, *Onychargia atrocyana*, *Ischnura senegalensis*, *Indaeschna grubaueri*, *Diplacodes trivialis*, *Lyriothemis biappendiculata*, *Orchithemis pulcherrima* and *Pantala flavescens* (marked with * in Table 2). Nevertheless, most of these species are common species, and all of them have been recorded elsewhere in Miri Division (Dow *et al*., 2021).

Table 2: Odonata species recorded from the Gerenai-Long Mekaba Scientific Expedition. * indicates new record for FMU Gerenai. # indicates photo record with no specimen taken.

No.	Species	Endemic	Sampling location							
			A	B	C	D	E	F	G	H
	Family Platystictidae									
1	*Drepanosticta* cf *dentifera* Kimmins, 1936	Yes		1♂			1♂			
2	*Drepanosticta rufostigma* (Selys, 1886)	Yes		3♂	3♂	3♂	3♂	4♂		
3	*Drepanosticta versicolor* (Laidlaw, 1913)	Yes			1♂			1♂		
	Family Calopterygidae									
4	*Neurobasis longipes* Hagen, 1887	No		3♂						
5	*Vestalis amaryllis* Lieftinck, 1965	No		1♂						1♂
6	*Vestalis amnicola* Lieftinck, 1965	Yes		3♂	1♂		3♂1♀			
7*	*Vestalis atropha* Lieftinck, 1965	Yes			1♂					
8	*Vestalis beryllae* Laidlaw, 1915	Yes			1♂					
	Family Chlorocyphidae									
9*	*Libellago semiopaca* (Selys, 1873)	No							1♂	
10	*Rhinocypha aurofulgens* Laidlaw, 1931	Yes		4♂			1♂			
	Family Devadattidae									
11	*Devadatta clavicauda* Dow, Hämäläinen & Stokvis, 2015	Yes		2♂	3♂1♀			2♂		1♂
12	*Devadatta somoh* Dow, Hämäläinen & Stokvis, 2015	Yes					1♂			
	Family Euphaeidae									

	Family Aeshnidae										
31	*Anax panybeus* Hagen, 1867	No	1♂						1♂		
32*	*Indaeschna grubaueri* (Förster, 1904)	No	1♂1♀		1♀						
33	*Tetracanthagyna* sp.	No		1♀							
	Family Gomphidae										
34#	*Heliogomhus* sp.	-			1♀						
35	*Ictinogomphus decoratus melaenops* (Selys, 1858)	No	1♂		1♂						
	Family Macromiidae										
36	*Epophthalmia vittigera* (Rambur, 1842)	No	1♂1♀								
	Family Synthemistidae										
37	*Idionyx* sp.	No		1♀							
	Family Libellulidae										
38	*Aethriamanta gracilis* (Brauer, 1878)	No			2♂						
39	*Brachydiplax chalybea* Brauer, 1868	No			1♂						
40	*Cratilla lineata* (Brauer, 1878)	No	1♂						1♀		
41	*Cratilla metallica* (Brauer, 1878)	No								1♂	
42*	*Diplacodes trivialis* (Rambur, 1842)	No			2♂						
43*	*Lyriothemis biappendiculata* (Selys, 1878)	No		3♂							
44	*Nannophya pygmaea* Rambur, 1842	No					2♂				
45	*Neurothemis fluctuans* (Fabricius, 1793)	No			1♂		1♂				

46	*Neurothemis ramburii* (Brauer, 1866)	No	4♂2♀		1♂					
47	*Neurothemis terminata* Ris, 1911	No			2♂					
48	*Onychothemis coccinea* Lieftinck, 1953	No		2♂						
49*#	*Orchithemis pulcherrima* Brauer, 1878	No		1♂						
50	*Orthetrum chrysis* (Selys, 1891)	No	2♂							
51	*Orthetrum glaucum* (Brauer, 1865)	No	1♂					1♂		
52	*Orthetrum purinosum schneideri* Förster, 1903	No			2♂					
53	*Orthetrum sabina* (Drury, 1773)	No			1♂					
54	*Orthetrum testaceum* (Burmeister, 1839)	No			1♂ 1♀					
55*	*Pantala flavescens* (Fabricius, 1798)	No	1♂							
56	*Rhyothemis triangularis* Kirby, 1889	No			2♂					
57	*Tetrathemis hyalina* Kirby, 1889	No			3♂					
58	*Tramea transmarina euryale* Selys, 1878	No							1♂	
59	*Trithemis aurora* (Burmeister, 1839)	No	2♂							
60	*Trithemis festiva* (Rambur, 1842)	No			2♂					
61	*Tyriobapta torrida* Kirby, 1889	No	2♂							
62	*Zyxomma obtusum* Albarda, 1881	No	1♂1♀							
	Total number of species		**16**	**21**	**32**	**3**	**6**	**8**	**6**	**5**



Figure 3. Some Odonata photos taken at Long Mekaba area. A: *Cratilla metallica*, B: *Heliogomphus* sp., C: *Lyriothemis biappendiculata*, D: *Orchithemis pulcherrima*, E: *Rhinocypha aurofulgens*, F: *Onychargia atrocyana*, G: *Coeliccia cyaneothorax*, and H: *Dysphaea ulu*.

With the data from Dow (2020), 94 Odonata species have known to occur in Gerenai FMU. This represents 25% of the Odonata species of Sarawak. Therefore, the Long Mekaba area, as well as the Gerenai FMU, is generally rich in Odonata fauna. The rich Odonata fauna may indicate the good health of the aquatic ecosystem at Long Mekaba area. It is also worth to note that 18 species recorded at Long Mekaba area during the scientific expedition are endemic to Borneo (Table 2). These endemic species are of conservational value.

The richness of Odonata fauna at Long Mekaba area indicates the good health of the aquatic ecosystem in the area. The various aquatic habitats in the area should be maintained and preserved for the conservation of Odonata. The vast diversity of Odonata with the presence of many endemic (Borneo) species may render the possibility of the development of dragonfly watching as an ecotourism product in Long Mekaba.

4 CONCLUSION

The Long Mekaba area, as well as the Gerenai FMU, is rich in Odonata fauna. The various aquatic habitat at Long Mekaba is refuge for some uncommon Odonata species endemic to Borneo. At present, 94 Odonata species are known to occur in Gerenai FMU. The rich Odonata fauna at Long Mekaba indicates the good health of the aquatic ecosystem at Long Mekaba area.

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I would like to thank Forest Department Sarawak for the invitation to the Gerenai-Long Mekaba HoB Scientific Expedition and Sarawak Forestry Corporation for the research premit (SFC.810-4/6/1-087) to conduct sampling at Long Mekaba area. I also thank Dr. Rory A. Dow for assistance in species identification of some Odonata specimens.

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BIRDS AND BATS SURVEY IN GERENAI-LONG MEKABA, BARAM, MIRI, SARAWAK

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Abstract: Bird and bat surveys were conducted in Long Mekaba, Gerenai FMU from 15th until 23rd September 2022. Gerenai-Long Mekaba's forest consists mainly of two types of forests, namely mixed dipterocarp forest and submontane forest. This study was conducted to determine the diversity and species composition of birds and bats at Gerenai-Long Mekaba, Ulu Baram by using mist-netting, bird watching, vocalization and echolocation. A total of 31 species of birds were successfully recorded: 20 species by mist-netting, and 1 species by bird watching and vocalization. As for bats, nine (9) species were recorded with five (5) species captured by using 10 mist nets and the remaining were recorded using a bat detector. Totally protected birds, based on the Wild Life Protection Ordinance, 1998, spotted from this area were Rhinoceros Hornbill (*Buceros rhinoceros*), Helmeted Hornbill (*Rhinoplex vigil*) and Oriental-Pied Hornbill (*Anthracoceros albirostris*). Meanwhile, the Trefoil Horseshoe Bat, *Rhinolophus trifoliatus*, a near-threatened species based on the IUCN Red List was also recorded. It is highly recommended that further studies need to be conducted at Gerenai-Long Mekaba to obtain a more comprehensive baseline data for the birds and bats population as part of an initial step in developing a management and conservation framework for the area.

Keywords: Bird watching, Conservation, Echolocation, Feeding guild, Mistnet, Submontane Forest

1 INTRODUCTION

Southeast Asia is facing rapid and largely unmonitored deforestation and habitat degradation (Myers et al., 2000; Gaveau et al., 2014). Although Borneo is well-known for its species richness, but high deforestation rates on this island are a serious conservation concern (Curren et al., 2004). Such events drastically alter the conditions of life for flora and fauna and will eventually become worse. Gerenai-Long Mekaba, specifically located at Gerenai Forest Management Unit (FMU) is a logged forest in Sarawak. Conservation of our tropical biodiversity especially near logged forest area need to provide adequate protection and sustainability for the habitats (duToit et al., 2004). It is crucial to identify the species that are represented in reserves and surrounding habitats for conservation planning purposes. This includes surveys of species distribution and species richness that are used in evaluations of conservation effectiveness (Jenning, 2000).

In this study, birds and bats are the focus of interest because both taxa exhibit features as bio-indicators that are important to the health and balance of ecosystems. Birds regulate the number of harmful insects in the environment, spread seeds, facilitate pollination, and maintain environmental sanitation (Tesfahunegny et al., 2016; Kiros et al., 2018). Similarly, bats are crucial for their roles as seed dispersers, pollinators, and regulators of forest insects. Diversity of birds is greatly impacted by changes in the landscape and vegetation. The occupancy and diversity pattern of the bird's species will be affected by the vegetation structure and composition of the forested area (Chettri et al., 2002; Sapian et al., 2018). Meanwhile, bats' occurrence varies with location, habitat type, and landscape cover in the area (Shafie et al., 2011) as the number of bat species frequently correlates with forest cover, patch size, and patch density (Gorresen & Willig 2004). The aim of this study is to determine the preliminary data for birds and bats of Gerenai-Long Mekaba area.

2 MATERIALS AND METHODS

1. Study Area

Located in the Gerenai Forest Management Unit (FMU), Batang Baram-Sungai Silat, Miri Sarawak, Long Mekaba has a total area of 148,305 hectares, in which 48% of it is within the Heart of Borneo area. Long Mekaba is generally dominated by two types of forest: Hill Dipterocarp Forest and Submontane Forest.

2. Sampling Method

Birds Survey

The bird survey was carried out using the mist-netting method. 10 mist nets were deployed for 9 sampling days. The mist nets operated from 0700 to 1700 hours and were checked every 2 hours to prevent the birds from entangling in the mist nets for a long period of time. The captured birds were measured, identified and released. The measurements include Sex, Weight (WT), Tarsus (TR), Bill Length (BL), Bill Depth (BD), Bill Width (BW), Head Bill (HB), Wing Length (WL), Wingspan (WS), Tail Anus (TA) and Tail (TL). Molting (Molt) and Brood Patch

(BP) were recorded in the data sheet for reference purposes. The birds were identified using field guidebooks; Phillipps' Field Guide to the Birds of Borneo (Phillipps & Phillipps, 2014) and Birds of Borneo (Myers, 2016).

Bats Survey

Meanwhile, a bat survey was carried out using the mist-netting method and acoustic monitoring by using a bat detector. 10 mist nets were deployed for 7 sampling days. The mist nets were operated from 1800 to 2100 hours and were checked every 30 minutes to prevent the bats from entangling and some species (insectivorous bats) may release themselves from the mist nets by chewing the nets to escape. The captured bats were measured, identified and released after taking their photos and echolocation calls (for insectivorous species). The measurements include Sex, Weight (WT), Forearm (FA), Ear Length (E), Tail length (T), hindfoot (HF), and Tarsus (TR). Facial features of each individual were identified as part of identification purposes following the field guidebook of Philipps and Philipps: Mammals of Borneo and Their Ecology (2018).

3 RESULTS AND DISCUSSIONS

1. Mist-Netting

The survey resulted in a total of 42 individuals with 20 species of birds. The most abundant species recorded was the Little Spiderhunter, *Arachnothera longirostra* with 12 individuals, followed by Hairy-backed Bulbul, *Tricholestes criniger* with 6 individuals. From 20 species mist-netted, one species; Grey-cheeked Bulbul, is listed as 'Vulnerable' (VU) in the IUCN Red List (2022) and four are listed as 'Near Threatened' (NT) comprising the Malaysian Blue Flycatcher, Streaked Bulbul, Chestnut-rumped Babbler and Buff-necked Woodpecker. According to IUCN Red List (2022), most of the species caught were listed as 'Least Concern' (LC).

Table 1: The list of bird species recorded from mist-netting.

Abbreviations: SWLPO 1998 = Sarawak Wild Life Protection Ordinance, 1998, TP = Totally Protected, P = Protected, NP = Not Protected, IUCN, LC = Least Concern, NT = Near Threatened, VU = Vulnerable.

COMMON NAME	SPECIES NAME	NO. OF INDIVIDUALS	IUCN
Black-naped Monarch	*Hypothymis azurea*	1	LC
Bornean Spiderhunter	*Arachnothera everetti*	2	LC
Bronzed Drongo	*Dicrurus aeneus*	1	LC
Brown-throated Sunbird	*Anthreptes malacensis*	2	LC
Buff-necked Woodpecker	*Meiglyptes tukki*	1	NT
Chestnut-rumped Babbler	*Stachyris maculata*	1	NT
Gold-whiskered Barbet	*Psilopogon chrysopogon*	1	LC
Grey-cheeked Bulbul	*Alophoixus tephrogenys*	1	VU
Grey-headed Babbler	*Stachyris poliocephala*	2	LC
Hairy-backed Bulbul	*Tricholestes criniger*	6	LC
Little Spiderhunter	*Arachnothera longirostra*	12	LC
Malaysian Blue Flycatcher	*Cyornis turcosus*	3	NT
Pacific Swallow	*Hirundo tahitica*	1	LC
Plain Sunbird	*Anthreptes simplex*	1	LC
Purple-naped Sunbird	*Kurochkinegramma hypogrammicum*	1	LC
Rufous Piculet	*Sasia abnormis*	1	LC
Spectacled Bulbul	*Rubigula erythropthalmos*	3	LC
Streaked Bulbul	*Ixos malaccensis*	1	NT
Thick-billed Spiderhunter	*Arachnothera crassirostris*	1	LC
Yellow-bellied Bulbul	*Alophoixus phaeocephalus*	1	LC
	Total species	**20**	

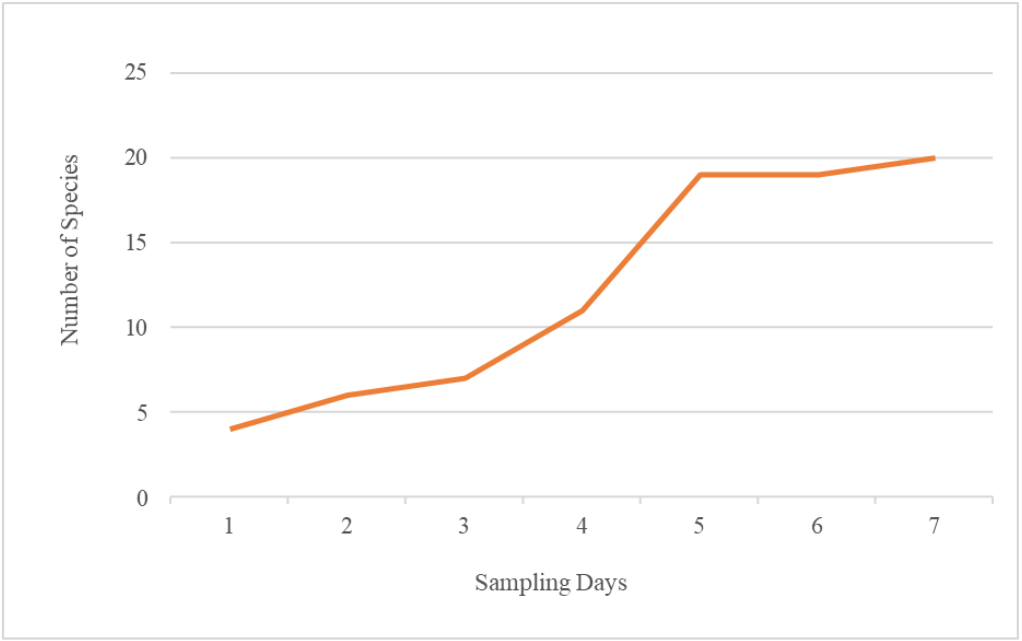


Figure 2: Bird species accumulation curve throughout the seven sampling days.

Figure 2 shows number of species caught per day throughout the sampling period. The number of species are gradually increasing per day but not yet reaching asymptote on the 7th day of sampling. Figure 2 shows that the bird species might increase again if the sampling period were to be extended. More species are yet to be discovered from this area. Moreover, extensive sampling by using different methods can be done to get a more complete data set.

3.2 Opportunistic Observation

Besides mist netting, bird species were also recorded by opportunistic encounter. Some species can be identified up to species level. Three hornbill species were seen from this area that are listed under Totally Protected Species in Sarawak's Wild Life Protection Ordinance, 1998 (SWLPO 1998). Other observed Protected Species were Owl sp. and Asian Paradise Flycatcher. Black-and-yellow Broadbill and Finch's Bulbul were listed as Near Threatened by IUCN and were also recorded roaming in this area. Overall, about 31 species of birds were recorded by mist netting and opportunistic encounter from Gerenai-Long Mekaba Scientific Expedition. The Combination of methods in wildlife sampling gave better results in documenting species diversity in an area.

Table 2: The list of bird species recorded from opportunistic observation.

Common Name	Species Name	IUCN	WLPO 1998
Helmeted Hornbill	*Buceros vigil*	CR	Totally Protected
Rhinoceros Hornbill	*Buceros rhinoceros*	VU	Totally Protected
Oriental-pied Hornbill	*Anthracoceros albirostris*	LC	Totally Protected
Oriental Magpie Robin	*Copsychus saularis*	LC	Unlisted
Black-and-yellow Broadbill	*Eurylaimus ochromalus*	NT	Unlisted
Finch's Bulbul	*Alophoixus finschii*	NT	Unlisted
Raffles Malkoha	*Rhinortha chlorophaea*	LC	Unlisted
Asian Paradise Flycatcher	*Terpsiphone paradisi*	LC	Protected
Tailorbird sp.	Unknown	-	Unlisted
Eagle sp.	Unknown	-	Unlisted
Owl sp.	Unknown	-	Protected
Total = 11 species			

3.3 Bats sampling

In this survey, only nine individuals of bats were caught by using mist nets, comprising five species from two families (Pteropodidae and Rhinolophidae). All species are protected under WLPO 1998, and one is listed as Near Threatened by the IUCN (2023). The sampling efforts were limited by rainy nights. Since mist nets did not effectively capture aerial insectivorous bats due to their foraging behaviour above the canopy, the acoustic method was used (O'Farrell and Gannon, 1999). The Acoustic method is a non-invasive way to identify aerial insectivorous bat species by their species-specific calls that forage around an area, using a bat detector (Appel *et al*., 2021). Three more additional species of echolocating bats (*Hipposideros cervinus*, *Hipposideros galeritus* and *Emballonura* sp.) were detected and identified from two families: Hipposideridae and Emballonuridae. A combination of both capture and acoustic methods is said to be more effective to document species richness in an area (Flaquer *et al*., 2007).

Method	Common Name	Scientific Name	No. of Individuals	WLPO 1998 Status	IUCN Status
Mist Nets	Sunda Short-nosed Fruit Bat	*Cynopterus bracyotis*	4	Protected	Least Concern
	Dusky Fruit Bat	*Penthetor lucasi*	2	Protected	Least Concern
	Long-tongued Nectar Bat	*Macroglossus minimus*	1	Protected	Least Concern
	Trefoil Horseshoe Bat	*Rhinolophus trifoliatus*	1	Protected	Near Threatened
	Lesser Tube-nosed Bat	*Murina suilla*	1	Protected	Least Concern
Acoustic	Cantor's Roundleaf Bat	*Hipposideros galeritus*		Protected	Least Concern
	Fawn Roundlead Bat	*Hipposideros cervinus*		Protected	Least Concern
	Sheath-tailed Bats	*Emballonura* sp.		Protected	Least Concern

Table 3: The list of bat species recorded from mist-netting and acoustic method.

4.0 CONCLUSION

For birds, a total of 31 species of birds were successfully recorded: 20 species by mist-netting, 11 species by bird watching and vocalization. Meanwhile for bats, nine (9) species were recorded with five species captured by using 10 mist nets and three (3) species recorded using a bat detector. However, the overall finding does not represent the birds and bat fauna of the entire area due to limited sampling efforts, duration of surveys and the types and structure of forest. These are the factors that directly affect the number of species and individuals recorded during this survey. The checklist from this survey provides initial findings and there could be potential rare species that have yet to be recorded in the Gerenai-Long Mekaba area.

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Question and Answer Session

PLENARY SESSION: 1	
SESSION CHAIRMAN/MODERATOR: MADAM MADELINE GEORGE PAU	
Question 1:	
Name	Dr Jason Hon
Agency	WWF Malaysia
Question to	Mdm Aileen Sim Kai Fang
Question	We recognize the significant ecological roles that wood plays within the forest ecosystem. Consequently, I would like to inquire about the variations you observed between the two sites. Specifically, why is there a higher presence of deadwood and leaf litter in T2 when compared to the standing biomass? Is there a particular explanation for the noteworthy quantities found in T2? Moreover, taking into account that deadwood naturally decomposes over time. It's reasonable to anticipate changes in carbon stock. How do you foresee the potential impact on carbon stock within the context of future carbon trading schemes? Do you expect stocks to either increase or decrease over time and, if so, how would you recommend monitoring these changes, particularly in relation to above-ground biomass at this specific site? Would you propose a reassessment of this site?
Answer	As I was not personally present during the expedition, I'm unable to provide firsthand observations of what I saw in the forest. Instead, my insights are based on the data collected and analyzed. Notably, T2 exhibits a significant accumulation of deadwood on the forest floor, although I cannot provide a specific reason for this observation. It's worth mentioning that while Dr Salwana referred to T1-T6 as pristine forests, the data I collected suggests that they may resemble logged forests due to the small diameter at breast height (DBH) of the trees. Regarding your second question about the decay of roots and carbon, it's essential to recognize that carbon undergoes transformations within the ecosystem, initially carbon is physically stored in wood, but as time passes, it may decompose into carbon

	dioxide and other gases. Nevertheless, it remains within the ecosystem. This is why researchers often study Net Primary Productivity (NPP) to assess the total carbon content within ecosystems. In my future plans, I intend to evaluate other forests in Sarawak although not necessarily focusing on this particular site.
Question 2:	
Name	Haji Mohd. Ridzuwan bin Endot
Agency	Forestry Department Peninsular Malayisia
Question to	Puan Hajah Halipah Bujang
Question	From your point of view, you did some soil study, is there any non-radioactive rare earth element (NRREE) in the study area in Long Mekaba?
Answer	It appears that our study did not delve into that level of detail. From what we observed, the area seems relatively undisturbed, as typically, human activities can significantly alter the soil profile. The indication is the recovering of mixed dipterocarp value which is growing quite well so maybe this is related to the study done by Puan Aileen on the difference of the recovering forest where she got higher value. To address your question more comprehensively, it might be beneficial for us to schedule a meeting and discuss the specifics of this particular area in greater depth.
Question 3:	
Name	Evelyn Jugi
Agency	Forest Department Sarawak
Question to	Puan Vilma Bados
Question	Your study is on the forest condition of the river buffer zone in selected Sarawak permanent forests. When you conduct the assessment, is it within the buffer zone itself or adjacent to the buffer zone? Are you looking at the different sites of the buffer zone itself? We are interested to know if the buffer zone established is effective in mitigating the impact of logging.

Answer	Currently, all our assessments have been conducted exclusively within the buffer zone. These buffer zones come in three different sizes, namely 10 m, 20 m and 50 m. So far, our findings haven't revealed any significant differences in terms of changes in the tree composition and stem structure. However, it is important to note that our study has definitely addressed the effectiveness of the buffer zones in mitigating the impacts of logging activities. To draw such a conclusion, we need to also consider factors like soil erosion rates and woody debris, as buffer zone serves as natural barriers to sedimentation and woody debris originating from the upper areas. While I can't provide a conclusive assessment at this time, precious studies conducted outside of Malaysia have shown that the appropriate width of buffer zones can vary, typically falling within the range of 9-30 m. The specific buffer zone width depends on the activities in the area as well as the geographical attributes of the catchment. In flatter regions, a smaller buffer zone width may suffice, whereas areas with steeper gradients may require wider buffer zones to effectively mitigate the impact of logging activities.
Question 4:	
Name	Pn Evelyn Jugi
Agency	Forest Department Sarawak
Question to	Dr Salwana Md. Jaafar
Question	Would it be possible for Trail 10 and 11 to be under the same forest type? If under the same forest type, in terms of diversity, you won't see the significant differences. For Trail 8 and Trail 11, is one of them primary, unlogged forest and the other is logged?
Answer	Yes, we categorized them under the same forest type, which is the mixed dipterocarp forest based on the texture of soil when we were sampling the soil and in terms of the tree diversity itself, it was considered mostly the usual mixed dipterocarp forest species. The reason why we were interested to do the research at the two trails is because on our first visit to both sites, we observed that the tree sizes were different, we thought we should get samples from these two trails because of time limitation and there were only 3 of us.
Question 5:	
Name	Dr Jason Hon

Agency	WWF Malaysia
Question to	Puan Hajah Halipah Bujang
Question	Would it be possible to use the properties of soil as an element to test the origin of soil and to see if it is possible to pinpoint the specific areas. If we have soil samples as evidence from a specific area, would it be possible to help in the investigation?
Answer	Our soil is different from other countries. For example, if someone from Kuching, Sarawak brings the soil sample to Canada, we may know the sample was not from Canada because the properties might be different in terms of content. But somehow, if the soil is from Miri and you want to identify if it is from Miri or Santubong, I believe it is impossible for now.

HEART OF BORNEO GERENAI - LONG MEKABA SEMINAR 2023

FOREST DEPARTMENT SARAWAK

12th-13th October 2023

The Waterfront Hotel, Kuching.

PLENARY SESSION: 2	
SESSION CHAIRMAN/MODERATOR: DR JASON HON	
Question 1:	
Name:	Tu Chu Lee
Agency:	Sarawak Biodiversity Centre (SBC)
Question to:	Siti Munirah Mat Yunoh
Question:	Is Thismia (Fairy Lantern) flowering in season? When is the best time to find or observe Thismia in the jungle?
Answer:	Different species of Thismia have different flowering seasons but it is best seen during wet season; especially in May onwards. However, some species can be seen throughout the year, but certain species can only be seen abundantly during the wet season. This year, the peak season is in May and probably next year at the same period of the time. Certain species can be seen during the dry season, but it is also depending on the locality. Because myco-heterophic plant is very small. It can easily be seen when flowering (because the flower itself is very attractive) or during fruiting period. For instance, during the Gerenai - Long Mekaba

	expedition, some species of Thismia have passed its flowering season, however some species are still flowering. I can conclude that observing Thismia is always by luck, with the right time and place but once you notice it, then it will be easier to spot another Thismia.
Question 2:	
Name:	Dr Jason Hon
Agency:	WWF Malaysia
Question to:	Madam Andi Maryani A. Mustapeng & Dr Yong Kien Thai
Question:	Does ferns & lycophytes have any ecological roles/ indicator or the forest health?
Answer:	Madam Andi Maryani A. Mustapeng : Some species of ferns and lycophytes act as forest health indicator. The presence of a particular species of ferns and lycophtyes indicate the area are being disturbed. Hence, once the area is being disturbed, certain species will extinct as they need primary conditions to survive.
	Any plant group plays certain roles in ecology. In fact, mosses (bryophytes) are ecologically significant to the nature compared to humans because; They act as a primary food source that support small organisms, (e.g., Invertebrates) in the whole food chain of the ecosystem. Presence of mosses (bryophytes) indicate certain level of humidity within the area. This is due to their features (tiny, simple and primitive), they are easily affected by the change of humidity in the surroundings. For example, some Mosses are epiphytic plants that depend on their host tress (tree trunk) and the micro environmental condition that these host provide. Besides, epiphytes are an important component in the forests, as they are sensitive to disturbance caused by humans. During the previous expedition in Lanjak Entimau showed that there is one group of mosses that are commonly prominent in highland area. Unexpectedly, this mosses also found during the Gerenai-Long Mekaba expedition. Thus, this proves that the condition of inland forest in Sarawak, especially the HoB area is extremely humid and capable to support highland biodiversity. Mosses also serve as a shelter for certain animals (especially for birds to build their nest). This is because of their spongy and soft texture; Besides, due to their spongy characteristic, mosses are able to store water. As water vapour and mist are available in the morning, these mosses will absorb the water and moisture from the surroundings. Then, it will be gradually released to the atmosphere as the surrounding temperature increases. Eventually, this process aids to regulate the local

	climate. Furthermore, all green plants including mosses are essential to absorb carbon dioxide and lowered the carbon dioxide level in the atmosphere. As a result, it helps to reduce the greenhouse effect.
Question 3:	
Name:	Mohamad Fitri Bin Azri
Agency:	Universiti Malaysia Sarawak (UNIMAS)
Question to:	Madam Andi Maryani A. Mustapeng
Question:	Are there any possibilities that one particular species to have different morphological characteristics (e.g., their spores) when growing in different altitudes such as lowland and highland?
Answer:	None. The character of ferns and lycophytes are specific and they remain identical despite the altitude differences. However, the species of ferns and lycophytes in highland area have smaller size compared to those in lowland area.
Question: 4	
Name:	William anak Lawrence Sinos
Agency:	Forest Department Sarawak
Question to:	All presenters
Question:	Based on studies and research conducted on plants or fungus and mosses during the expedition, are there any local names for each species?
Answer:	Madam Ling Chea Ying To simplify, this is depending on the usage of the plant, if it is locally used by the local community, then it might have a local name. But for unknown and newly discovered plants, the researcher usually uses the scientific name to indicate the plant species.
Second presenter to Dr. Akmal (is there any local name for pandan?)	Dr Akmal Raffi I am agreeing with Mdm. Ling's statements on this matter. If the plant is utilised, then it will definitely have names but it will be varies based on the locality. In the case of Gerenai-Long Mekaba expedition, three (3) genera of pandan are discovered and upon discussion with local communities, certain pandan species do not have a local name. Thus, any types of pandan are generally named as *pandan* despite its differences in features. However, the local community is not obligated to give a local name if they are not familiar nor utilized the particular species. For instance, pandan is known as Da'ah by the Kenyah community because it is typically used for mat-making and also consumption.

Dr Yong (Dr. Akmal to Dr Yong: is there any local name for mosses)	Madam Siti Munirah Mat Yunoh Fairy lantern is an English common name given to Thisimia because it shares a resemblance with a fairy lantern. However, the local name of Thisimia may varies depending on the locality of the species. For example, in peninsular Malaysia, Thisimia is often known as "kulat" by the Orang Asli community due to its resemblances with mushroom. Hence, in Sarawak specifically, I believe that Thisimia might also have its own local name given by the local community based on their particular locality, ethnicity and language. Dr Yong Kien Thai If we want to encourage the local community to be more appreciative on the species diversity of the forest, then we must create the usage of it considering that a plant or an organism is only named when it is utilised. Moreover, with the advantage of modern technologies (e.g. internet access) and better education, it is easier to motivate the local community to be aware of the species diversity within their area. Consequently, it enables them to identify plants and be aware of its conservation status although the plants are not utilized by them. Indirectly, this is beneficial in terms of conservation effort because it encourages the local communities to use scientific names in their daily livelihood and by then, we are able to foster sense of belonging among the communities to engage them in long-term conservation. Besides, we live in country that is rich in biodiversity, if we are not able to appreciate our own biodiversity, then nobody will.
Question 5	
Name:	Muhamad Rahman Hakim Abdullah
Agency:	Universiti Malaysia Sarawak (UNIMAS)
Question to:	Dr Akmal Raffi
Question:	Will the extinction of endemic species affect the ecosystem? Because the other ecosystem without the endemic species can still have a balanced ecosystem.
Answer:	Madam Ling Chea Ying Endemic species is a term used to describe the distribution of a particular plant or organism that is found in a particular area. In general, all plants and organisms support an ecosystem. In fact, each one of the species or organisms has a niche or a specific role that it plays within the ecosystem. However, the types of species do not affect the balance of the ecosystem. Instead, it is affected by the number of species within the habitat. Likewise, every species has its own dynamic; Even

Dr Yong (Dr. Akmal to Dr Yong: is there any local name for mosses)	Madam Siti Munirah Mat Yunoh Fairy lantern is an English common name given to Thisimia because it shares a resemblance with a fairy lantern. However, the local name of Thisimia may varies depending on the locality of the species. For example, in peninsular Malaysia, Thisimia is often known as "kulat" by the Orang Asli community due to its resemblances with mushroom. Hence, in Sarawak specifically, I believe that Thisimia might also have its own local name given by the local community based on their particular locality, ethnicity and language. Dr Yong Kien Thai If we want to encourage the local community to be more appreciative on the species diversity of the forest, then we must create the usage of it considering that a plant or an organism is only named when it is utilised. Moreover, with the advantage of modern technologies (e.g. internet access) and better education, it is easier to motivate the local community to be aware of the species diversity within their area. Consequently, it enables them to identify plants and be aware of its conservation status although the plants are not utilized by them. Indirectly, this is beneficial in terms of conservation effort because it encourages the local communities to use scientific names in their daily livelihood and by then, we are able to foster sense of belonging among the communities to engage them in long-term conservation. Besides, we live in country that is rich in biodiversity, if we are not able to appreciate our own biodiversity, then nobody will.
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	though a species is still in the ecosystem, its niche will be deteriorated as the numbers decrease. As a result, this will affect the ecosystem's structure and create an ecological imbalance. Hence, the extinction of certain type of endemic species is not affecting the collapse of an ecosystem but the species richness does.



Appendix

Photos from the fieldwork at the Gerenai-Long Mekaba Scientific Expedition, held from September 13th to 25th, 2022.



Photos from Heart of Borneo Seminar 2023, Gerenai- Long Mekaba Scientific Expedition held at The Waterfront Hotel, Kuching from 12th-13th October 2023

















PROCEEDINGS OF THE HEART OF BORNEO (HOB) SARAWAK SEMINAR 2023:

THE SCIENTIFIC EXPEDITION TO GERENAI-LONG MEKABA, SARAWAK

12TH-13TH OCTOBER 2023
WATERFRONT HOTEL, KUCHING

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