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Front cover: Leafy twig of *Ternstroemia aneura*, the most common species of the genus in Borneo. (Photo: Suzana Sabran)

The establishment of Long Term Ecological Research (LTER) plots in the Sepilok mangroves

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Abstract. A mangrove Long Term Ecological Research (LTER) site in Sepilok Laut was set up in 2017. This is to gain a better understanding of the ecology and diversity of wetland ecosystems. For the establishment of the site, five circular permanent sampling plots (PSP) of 15-m radius each were set up along the boardwalk connected to the Sepilok Laut Reception Centre. Fieldwork for data collection was carried out in June and July, 2017. A total of 218 individual trees from 233 stems were recorded, representing the main and back mangrove zones. Eleven species were documented, from eight families and 10 genera. Rhizophoraceae is the most dominant and important family in all plots. *Ceriops tagal* recorded the highest relative abundance percentage (44.5%), followed by *Rhizophora apiculata* (25.7%), *Lumnitzera littorea* and *Bruguiera sexangula* (6.9% respectively). A total of 4.6±1.1 species were recorded in each circular plot, with 43.6±14.2 individuals. Two new plant records were documented for Sepilok (Mangrove) Forest reserve, namely *Diospyros ferrea* and *Syzygium leucoxylon*. As expected, the plant diversity in mangroves is low. The mean value of Shannon-Wiener diversity index is 1.12 while Simpson index is 2.89, Margalef index is 0.99 and Pielou's evenness index is 0.63. About 70% of all recorded stems in the plots are represented by the lowest diameter class category, between 10.0 cm to 19.9 cm, and 20% of them are from 20.0 cm to 29.9 cm diameter class. The tree canopy height is between 16 m to 22 m high. The mean carbon density in the LTER site is 159 t C/ha. The significance and the way forward for the mangrove LTER site in Sepilok Laut are discussed in this paper.

Keywords: mangroves, Long Term Ecological Research (LTER) site, Sepilok Laut

INTRODUCTION

Mangroves in Sabah

Mangroves exist as an interface between the land and sea, where plants have evolved special adaptive features to survive in such an environment. They are important provider of many goods and services to mankind, including serving as biological barriers against tsunami, cyclones, floods and other environmental calamities. The mangrove habitats are important breeding ground for various marine as well as terrestrial life forms (Nilus *et al.* 2010, Clough 2013, Ong & Gong 2013, Baba *et al*. 2013).

Approximately 3.7% (577,700 ha) of the world's mangrove area are distributed in Malaysia, and Sabah disproportionately accounts for 59% (341,000 ha) of the country's total. A total of 95.7% of the mangroves in Sabah are gazetted as forest reserves under the Forest

Enactment, which is administered by the Sabah Forestry Department (Nilus *et al*. 2010). They are mainly classified under the Mangrove FR (Class V), with a few classified under Protection FR (Class I), Virgin FR (Class VI) and Amenity FR (Class IV) (Tangah *et al.* 2017).

The mangroves of Sabah can be divided into three broad mangrove zones, i.e. seaward or riverine margin, main mangrove and back mangrove zones. Nilus *et al*. (2010) provided a detailed account of Sabah's mangroves, featuring some 51 true mangrove plant species and their common associates, as well as some of the common and interesting mangrove fauna.

Establishment of a mangrove LTER site in Sabah

Sabah's mangroves are largely protected, whereas production is limited to small scale extraction of poles. The department has established a long term collaboration with the International Society for Mangrove Ecosystems (ISME) and Tropical Biosphere Research Centre (TBRC) of Ryukyus University in Okinawa, Japan, on the sustainable management of mangrove ecosystems (Tangah *et al*. 2015 & 2017). During the 2nd Sabah's Ramsar Conference in November 2016, the keynote speaker, Dr Ong, J.E., who is also the Honorary Chief Technical Advisor for ISME, proposed for the setting-up of a mangrove Long Term Ecological Research (LTER) site in Sabah, to be spearheaded by the Sabah Forestry Department (Ong 2017). Recognizing the importance of mangroves to mankind, the Chief Conservator of Forests, Datuk Sam Mannan, agreed for a mangrove LTER site to be established in order to monitor the health (e.g. from changes in growth rates and demographic shifts) as well as to gain a better understanding of various ecological aspects of mangrove ecosystems.

The establishment of the mangrove LTER site was discussed in the 13th Project Steering Committee (PSC) Meeting of the SFD-ISME Collaborative Project on Mangrove Rehabilitation in Sabah, held on 20th of March, 2017 at the Forestry Headquarters in Sandakan. A committee was formed and tasked to establish the mangrove LTER site, with advice provided by members of ISME.

MATERIALS & METHODS

Mangrove LTER site

The mangrove LTER site was set up in Sepilok Laut of the Sepilok (Mangrove) Forest Reserve (5^{o}48'N, 117^{o}57'E) in Sandakan (Figure 1). The mangrove is a Virgin Jungle Reserve (Class VI), comprising 1,235 ha and is connected to Kabili-Sepilok Forest Reserve, a Virgin Jungle Reserve of 4,294 ha (SFD 2017). The management of this forest reserve is under the jurisdiction of the Sandakan District Forestry Officer, with his staff based at the Sepilok Laut Reception Centre.

Sepilok Laut was chosen due to its accessibility, logistics and convenience. Located within the Sandakan Bay, the mangrove LTER site in Sepilok Laut is only about 20 minutes boat ride from Sandakan. Another route is through a four-hour forest trekking from the Rainforest Discovery Centre in Sepilok. Infrastructure is also available, i.e. the Sepilok Laut

Reception Centre (SLRC), for researchers and staff members. Much research has been conducted in Sepilok Laut in the past and these data can be used to support the establishment of the LTER site. Apart from the flora and fauna mangrove research, biomass ground-truthing was conducted in Sepilok (Mangrove) Forest Reserve (as part of the Carnegie Airborne Observatory (CAO) Project, using Light Detection and Ranging (LiDAR) technology). Another project has also been initiated using drone flights (in collaboration with the TBRC of Ryukyus University in Okinawa, Japan) to investigate the gap formation from the dying trees within the mangroves. Mangrove rehabilitation has also been carried out in patches in the disturbed areas adjacent to Sepilok Laut.

For the establishment of the mangrove LTER site, five circular permanent sampling plots (PSP) of 15-m radius each were set up along the boardwalk connected to the Sepilok Laut Reception Centre (Figures 2 & 3). The size of each plot is 0.07 ha and the soil of all the plots is classified under Weston association. Plot 1 is located towards the seaward margin while the location of other plots is towards the landward margin (see Figure 3). Each plot was set up 50-80 m apart from the plot centre and 10 m away from the boardwalk. The plots are advocated as an approach that is robust in documenting detailed changes in forest structure and composition. They also provide baseline distribution data for species and provide information on the habitats of a particular site. The continuous long-term monitoring of these plots would provide valuable information on changes or the lack of changes in plant diversity and richness, growth, mortality, regeneration and dynamics of the sampled forest. Monitoring of permanent plots by measuring these characteristics of the vegetation is likely to remain relevant in the face of changing or evolving environmental issues. Often, it is common place for such plot data to be used to address issues beyond the original enquiries at time of establishment, progressing to the development of new lines of enquiries or research avenues (e.g. measuring carbon storage).

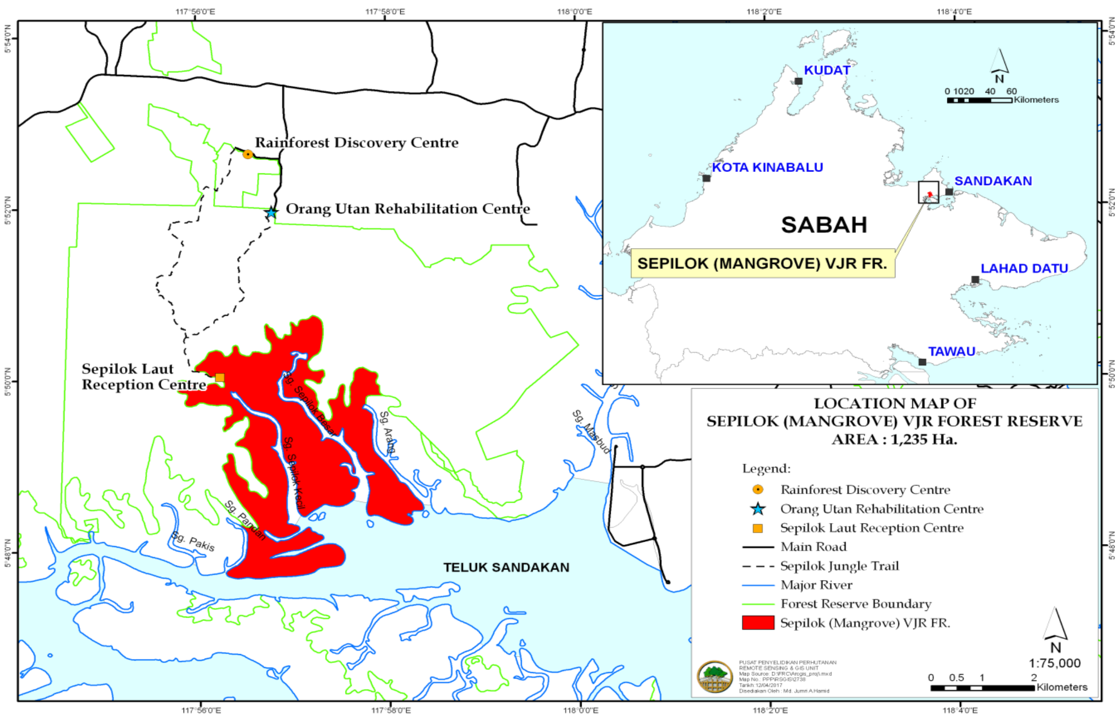

Figure 1. Location of the LTER site adjacent Sepilok Laut Reception Centre within the Sepilok (Mangrove) FR.

Figure 2. The mangrove LTER site (circled in yellow) along the 700-m boardwalk connected to the Sepilok Laut Reception Centre (source: Shin Watanabe).

Figure 3. Location of the five circular plots along the boardwalk connected to the Sepilok Laut Reception Centre.

Data collection

Fieldwork for the data collection of the five permanent circular plots was carried out in June and July, 2017. In each plot, all trees above 10 cm in diameter at breast height were measured while for height, all trees above 20 cm in diameter were taken in account. The tree diameter was measured using a diameter tape (model: EBoot Tape Measure) at 1.3 m above the ground while for tree with stilt roots, it was measured at 30 cm above the highest stilt root developed from the main trunk. All measured points were marked with red paint. The height was determined with a hypsometer (model: Laser Technology TruPulse 360^o). All measured trees were labelled with aluminium tags. A GPS gadget (model: Garmin GPS 60CSx) was used to determine the coordinates of each tree. Trees with multiple stems (stilt roots) and dead standing trees were noted during the assessment. All the measured trees were identified down to the species level. The salinity (0-100 ‰) of the water was taken using a salinometer (model: Atago S/Mill-E).

Data analysis

Similarity among plots was calculated using Jaccard's Coefficient in cluster dendrogram analysis provided in Multi-Variate Statistical Package Software, distributed by Kovach Computing Services. Cluster analysis encompasses a number of different algorithms that examining data and group objects of similar degree of association between two objects is maximal if they belong to the same group and minimal otherwise (http://www.statsoft.com).

The mangrove plant diversity was measured using various indices, including Shannon-Wiener (H'), Simpson (D) and Margalef (d). Shannon is among the most widely used diversity index in ecological studies and it often increases as both richness and evenness of the community increases. Simpson is more sensitive towards dominant species within the community while Margalef strongly dependent on sampling size and effort. For evenness, Peilou (J') was used to evaluate the data. All data were analysed using Species Diversity & Richness (SDR) version 4.1.2 software developed by Seaby and Henderson (2007).

The importance value is the relative dominance of each species or family of trees enumerated in the plots that was calculated as the average of relative tree density and relative basal area as follows (Brower & Zar, 1977):

Relative tree density = [∑ tree density of species or family I / ∑ tree density of all species or families] × 100
Relative basal area = [∑ basal area of species or family I / ∑ basal area of all species or families] × 100
Relative dominance = (Relative tree density + Relative basal area)/2

Results of the importance value of each family and species of trees enumerated in the plots were calculated using Microsoft EXCEL.

To determine the carbon stock of aboveground components in mangrove forest, it is necessary to firstly determine the total biomass of aboveground components of the tree. In this study, the biomass was estimated by using an allometric equation developed by Komiyama *et al*. (2005).

Aboveground biomass (kg) = $0.251\rho(\mathrm{DBH})^{2.46}$
DBH = Diameter at breast height (cm)
ρ = wood density (g/cm^3) (Burgess 1966)

The carbon stock of the aboveground biomass is then determined by multiplying the biomass with carbon concentration or percentage in the plant (50%).

RESULTS & DISCUSSION

Mangrove zonation

The mangroves in the Sepilok Laut LTER site can be divided into two zones, namely the main mangrove zone and the back mangrove zone, based on the cluster dendrogram analyses (Figure 4). Plots 1-4 are grouped under the main mangrove zone while Plot 5 is categorized under the back mangrove zone. The salinity of Plots 1-3 is between 30 to 35% while the salinity of Plots 4 & 5 is 25% respectively.

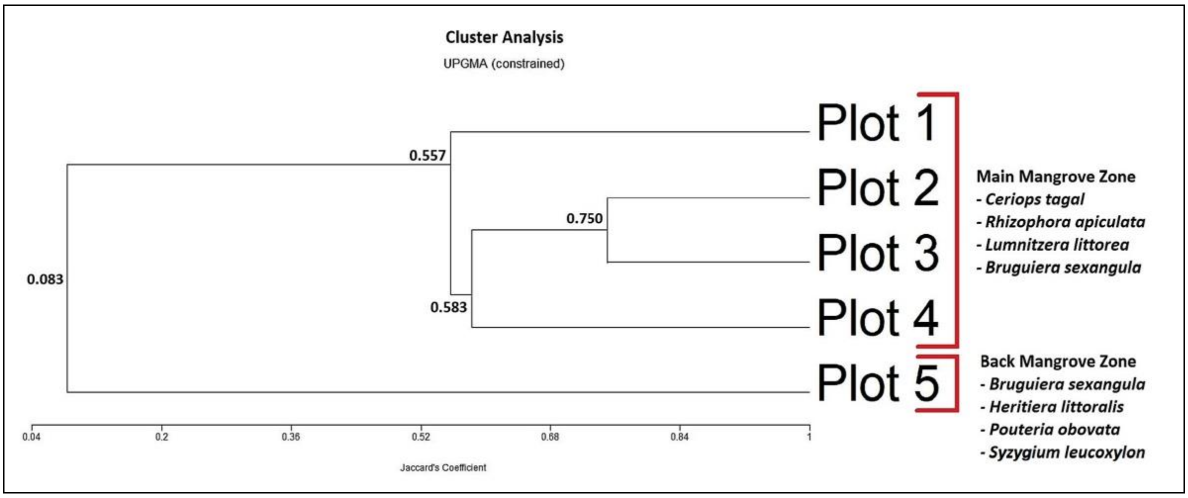

Figure 4. Cluster dendrogram analysis of the mangrove vegetation of the five circular plots in the LTER site of Sepilok Laut.

Distribution of mangrove vegetation

A total of 218 individual trees from 233 stems were recorded from the five permanent circular plots in Sepilok Laut. All data from the five plots are shown in Appendix 1. From the survey, 10 species were documented, representing eight families and 10 genera. Rhizophoraceae is the most dominant and important family in all plots, with four species in the LTER site. Other families are Myrtaceae, Malvaceae, Sapotaceae, Ebenaceae, Combretaceae, Meliaceae and Rubiaceae, with just one species each (Table 1). The importance value of each family in every plot is given in Appendix II.

Table 1. Individual density of families for trees ≥ 10 cm dbh in all five circular plots of the LTER site in Sepilok Laut.

Family	Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Combretaceae	*Lumnitzera littorea*	8	1	1	5	
Ebenaceae	*Diospyros ferrea*					1
Malvaceae	*Heritiera littoralis*				4	9
Meliaceae	*Xylocarpus granatum*			1	1	
Myrtaceae	*Syzygium leucoxylon*					13
Rhizophoraceae	*Bruguiera sexangula*	7			1	8
	Ceriops tagal	36	35	24	2	
	Rhizophora apiculata	9	17	18	12	
Rubiaceae	*Scyphiphora hydrophyllacea*	1				
Sapotaceae	*Pouteria obovata*					5
Total		61	53	44	25	35

Mangrove species richness, abundance and diversity

On average, 4.6±1.1 species were recorded in each circular plot, with 43.6±14.2 individuals. Species richness and abundance in each plot are shown in Figure 5.

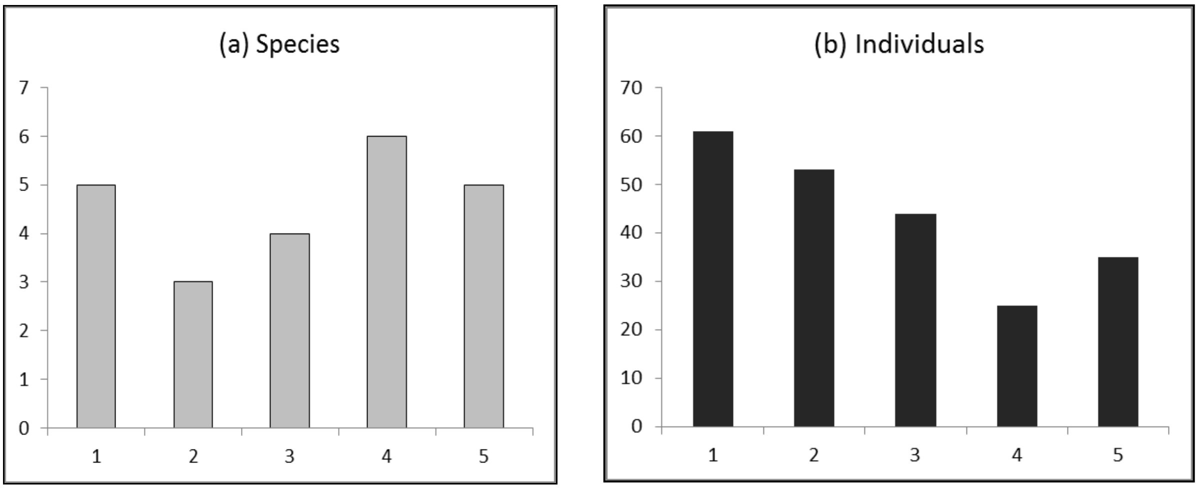

Figure 5. Number of mangrove plant species (a) and individuals (b) in the five plots of the LTER site in Sepilok Laut.

The mean value of Shannon-Wiener diversity index for the mangrove LTER site is 1.12 while Simpson index is 2.89, Margalef index is 0.99 and Pielou's evenness index is 0.63

(Table 2). For comparison on Shannon's index, Dinagat Island in the Philippines (Canizares & Seronay 2016) recorded a mean index of 1.856, while Sibuti mangroves in Sarawak (Shah *et al*. 2016) has a value of 1.18. In another study by Lo *et al*. (2011) in Semporna mangrove forest in Sabah, the Shannon's index was 0.711 in non-disturbed mangroves while the value was higher in disturbed mangroves, 1.725. Hence, it is common that plant diversity in mangroves is low and seldom exceeds the value of 2. Generally, diversity is considered high when the value is more than 3 in the Shannon-Wiener's index. Plant diversity is often higher in disturbed mangroves as there is a mixture of other plants within the site, especially towards the landward margin. This is reflected in Plots 4 and 5 in this study. The values for Shannon and Simpson diversity indices as well as Pielou evenness index were consistently higher than Plots 1, 2 and 3. Of all the plots, Plot 2 recorded the lowest value for all the indices because it has only three species, and two of them are dominant species, namely *Ceriops tagal* and *Rhizophora apiculata* with 35 and 17 individuals respectively (see Table 1). The value is prominently indicated in Simpson's index which is sensitive towards dominant species. Such disproportionate distribution of plant species in Plot 2 is also clearly indicated by the Pielou evenness index.

Table 2. Mangrove plant diversity in the five plots of the LTER site in Sepilok Laut and comparison with other sites.

Plot	Shannon (H')	Simpson (D)	Margalef (d)	Pielou (J')
1	1.18	2.56	0.97	0.66
2	0.71	1.89	0.50	0.40
3	0.87	2.20	0.79	0.48
4	1.43	3.61	1.55	0.80
5	1.42	4.10	1.12	0.80
Mean Sepilok Laut LTER site	1.12±0.32	2.89±0.94	0.99±0.39	0.63±0.18
Sibuti mangroves, Sarawak Shah *et al*. (2016)	1.18	n.a.	0.54	1.41
Semporna undisturbed mangroves, Sabah Lo *et al*. (2011)	0.711	n.a.	n.a.	n.a.
Semporna disturbed mangroves, Sabah Lo *et al*. (2011)	1.725	n.a.	n.a.	n.a.
Dinagat Island mangroves, Philippines Canizares & Seronay (2016)	1.856	n.a.	n.a.	n.a.

*n.a. = not available.

Mangrove species composition

Among the 10 mangrove species documented from the LTER site, *Ceriops tagal* recorded the highest relative abundance percentage (44.5%), followed by *Rhizophora apiculata* (25.7%), *Lumnitzera littorea* (6.9%) and *Bruguiera sexangula* (6.9%). The importance value of each species in every plot is given in Appendix III. *Ceriops tagal* is a medium-sized tree, locally known as 'Tagal' or 'Tengar'. It is locally abundant in Sabah, forming dense stands on landward edge of tidal forests and prefers clay substrates (Nilus *et al*. 2010). The bark contains tannin that is used to produce dye and it is much sought after by smugglers from the neighbouring country (SFD 2013). *Rhizophora apiculata* is another dominant mangrove species in Sabah. Locally known as 'Bangkita' or 'Bakau Minyak', it is commonly used in mangrove rehabilitation due to its robustness and abundant availability of propagules (Nilus *et al*. 2010 & Tangah *et al*. 2015). *Lumnitzera littorea* is a large mangrove tree, locally known as 'Geriting Merah' or 'Teruntum Merah'. It prefers soft, muddy substrate at the landward margin where tidal inundation is rare. The timber is valued for its extreme durability (Nilus *et al*. 2010).

Two species were noted having the lowest relative abundance percentage of 0.5% respectively, namely *Scyphiphora hydrophyllacea* and *Diospyros ferrea*. The former is a mangrove bushy shrub, known as 'Landing-landing' or 'Chengam', with its leaf extracts used to treat stomach problem while the latter is a tree, known as 'Kayu Malam' which is valued for its good timber pattern. Interestingly, *Diospyros ferrea* is a new record for Sepilok (Mangrove) Forest Reserve. Another species, *Syzygium leucoxylon*, is also a new record for this reserve. Both species are found in Plot 5, which is located towards the landward margin of the mangrove forest.

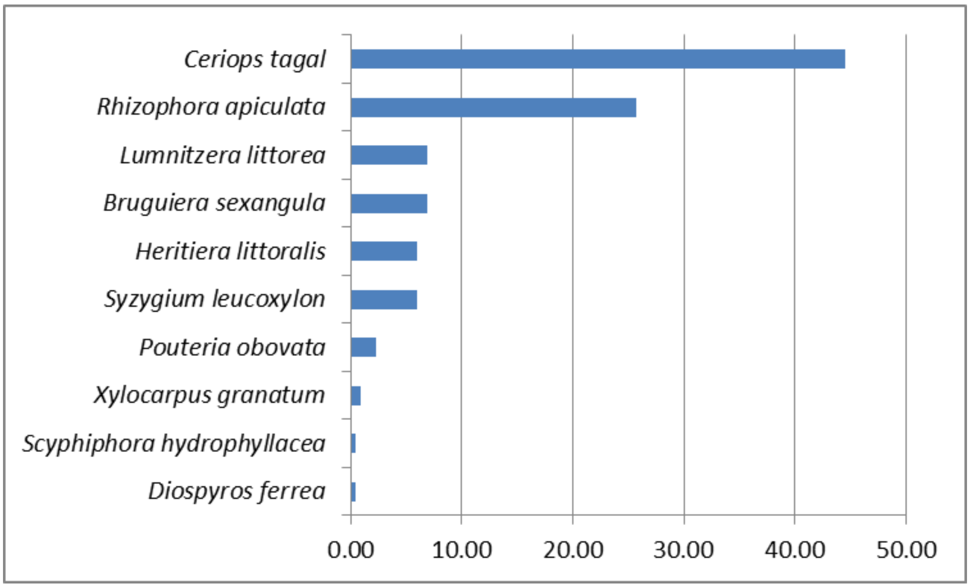

Figure 6. The relative abundance percentage of mangrove species in the LTER site of Sepilok Laut.

Mangrove tree diameter, density and basal area

Based on the data enumerated from the five plots, the mangrove in Sepilok Laut is mainly dominated by smaller stature trees (Figure 7). About 70% of all recorded stems in the plots are represented by the lowest diameter class category, between 10.0 cm to 19.9 cm, and 20% of them are from 20.0 cm to 29.9 cm diameter class. There is a scarcity of large trees with 30 cm dbh and above.

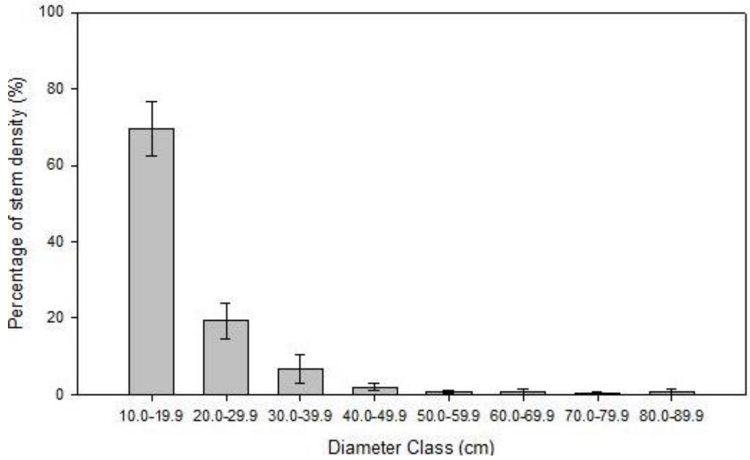

Figure 7. Mean tree density in 10 cm dbh intervals for all five plots in the LTER site of Sepilok Laut.

From the five plots, there is an average of 43.6 trees with 46.6 stems in each 0.07 ha plot, covering a mean density of 622.8 trees per ha or 665.7 stems per ha. The stems cover a basal area of 23.6 m^2 per ha (Table 3). The highest numbers of stems and basal area was recorded in Plot 1, whereas the lowest stem density and basal area were recorded in Plot 4 and Plot 5 respectively. *Rhizophora apiculata* has the affinity to produce from one to three stems with a dbh of 10 cm. The contribution of multiple stems to all stems in this forest is between 4 to 17% (minor to substantial component of total tree density).

Table 3. Density and basal area of trees ≥ 10 cm dbh for the five 0.07-ha plots in the LTER site of Sepilok Laut. Density and basal area are presented separately for all individual trees ([a]) and all stems ([b]). Basal areas are for all stems.

Plot No	Number of individuals[a]	Number of stems[b]	Basal area[b]	Density[a] (ha^{-1})	Density[b] (ha^{-1})	Basal area (m^2 ha^{-1})[b]
1	61	65	2.2	871.4	928.6	31.9
2	53	57	1.2	757.1	814.3	16.5
3	44	46	1.6	628.6	657.1	22.8
4	25	30	2	357.1	428.6	29.2
5	35	35	1.2	500	500	17.5
Mean	43.6	46.6	1.7	622.8	665.7	23.6

For individual density of tree families, Rhizophoraceae is the most dominant and important family in all the five plots (Table 4). This family contributed about 20-98% and 42-83% of the total stem density and basal area for all plots, respectively. The two most prominent species from this study site, namely *Ceriops tagal* and *Rhizophora apiculata*, belong to the family Rhizophoraceae. As the salinity of the seawater decreases, the stem density and basal area of Rhizophoraceae also decreases. Other important families that contributed to the structure of the mangrove LTER site in Sepilok Laut are Combretaceae and Meliaceae. The Combretaceae trees, namely *Lumnitzera littorea*, usually occurs in low density but as large individuals that contributed about 12-52% of the total basal area.

Table 4. Individual density of families for trees ≥10 cm dbh in all five plots of the LTER site in Sepilok Laut.

Family	Plot 1 (Salinity 35%)		Plot 2 (Salinity 31%)		Plot 3 (Salinity 30%)		Plot 4 (Salinity 25%)		Plot 5 (Salinity 25%)	
	Stem Density	Basal Area	Stem Density	Basal Area	Stem Density	Basal Area	Stem Density	Basal Area	Stem Density	Basal Area
Combretaceae	8	1.28	1	0.13	1	0.20	5	1.18		
Ebenaceae									1	0.01
Malvaceae							4	0.09	10	0.17
Meliaceae					1	0.07	1	0.10		
Myrtaceae									12	0.24
Rhizophoraceae	56	0.94	56	1.02	44	1.33	20	0.67	7	0.58
Rubiaceae	1	0.01								
Sapotaceae									5	0.22
Grand Total	65	2.24	57	1.15	46	1.60	30	2.05	35	1.23

Mangrove tree canopy height

On average, the tree canopy height for all plots was recorded between 16 m to 22 m high. Many of the tall trees were recorded in Plot 5, with seven trees more than 22 m, and many are *Bruguiera sexangula*. In Plot 1, *Lumnitzera littorea* is the prominent tall mangrove species. In comparison, the mean height of the mangroves in Sibuti, Sarawak, is lower, at 13.53 m. *Rhizophora apiculata* is the tallest species, with a mean of 15.18 m (Shah *et al*. 2016). In the Dinagat Island mangroves, Philippines, the average height of mangroves is only 5.87 m (Canizares & Seronay 2016).

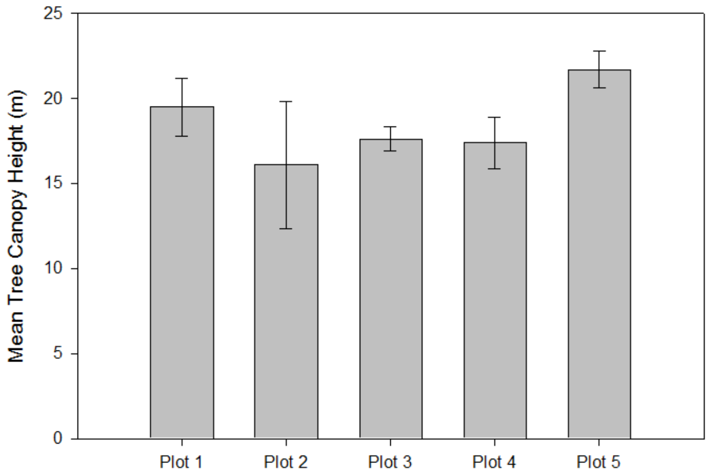

Figure 8. Mean tree canopy height for trees ≥10 cm dbh for the five plots of the LTER site of Sepilok Laut.

Estimated mangrove carbon stock density

The mean carbon stock density in LTER site is 159 t C/ha (Table 5). Plot 2 has the lowest carbon density of 96 t C/ha and Plot 4 has the highest carbon density of about 228 t C/ha. In comparison, Putz & Chan (1986) reported that over the 1950-1981 observation period, the biomass in Matang Mangroves in Perak ranged from 270 to 460 t/ha, which is equivalent to carbon stocks ranging from 135 to 230 t C/ha, with a mean of 204 t C/ha. In 2011, the carbon stocks of Matang Mangroves ranged from 1.01 to 259.68 t C/ha (Hamdan *et al*. 2013).

Table 5. Aboveground biomass and carbon stock density of the LTER site in Sepilok Laut.

Plot	Aboveground Biomass (t/ha)	Carbon Stock Density (t/ha)
1	430	215
2	193	96
3	310	155
4	459	229
5	203	101
Mean	319	159

Future research and the way forward for the mangrove LTER site in Sepilok Laut

The mangrove plant data collected thus far will serve as baseline information for future research initiatives as well as mangrove environmental monitoring purposes. As more than half of the mangroves in Malaysia are located in Sabah, it is pertinent and important to have a site with fundamental data dedicated for research. Some mangrove research sites were established in the past, not only in Malaysia but also in various other tropical countries. However, due to logistical difficulties as well as various other reasons, many of these sites are not properly maintained, with some being abandoned (S. Baba & J.E. Ong, pers. comm.). Accessibility and conducting research in mangroves are very challenging. Besides the harsh environment with irritating biting insects, walking and balancing on the mangrove floor can be a daunting task, depending on the tidal level. The presence of crocodiles and snakes could also adversely affect research in such an environment. In eastern Sabah, security has been an issue since the Tanduo intrusion in Lahad Datu in 2013, followed by a number of kidnapping incidences by intruders from the neighbouring country. All these were taken into consideration when setting up the mangrove LTER site in Sabah.

In terms of accessibility, logistics as well as security, the location of the LTER site is appropriate not only for short and long term research but also for environmental education on mangrove ecosystems. With the baseline information, other researchers from local and international agencies are welcome to conduct their mangrove-related research in the LTER site. The Mangrove Unit of the Forest Research Centre, Sepilok will continue to carry out annual (later to be biennial) measurement of the permanent circular plots in order to assess the long term ecological changes in the site.

The establishment of the LTER site can be expanded in future in other areas within the Sepilok (Mangrove) Forest Reserve. For example, the present LTER site covers only the main and back mangrove zones. The seaward mangrove zone, which is the forefront of the mangrove zonation, is not represented here. Hence, some plots representing this zone may be established at an adjacent area in future.

CONCLUSION

The baseline data procured from the LTER site are fundamentally important for future research work. It is envisaged that the setting-up of the LTER site will benefit the Sabah Forestry Department in gaining a better understanding of the mangrove ecosystems which can support sustainable mangrove management throughout the state. Ecological, diversity and carbon data are being collected every year to monitor the status of this site. Collaboration with international agencies, such as ISME and Ryukyus University, Japan, as well as other academic institutions in the future on research in the LTER site would enhance the department's credibility and recognition in managing the mangroves.

ACKNOWLEDGEMENTS

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Appendix I. The five circular plots (0.07 ha each) of the mangrove LTER site in Sepilok Laut.

PLOT 1

Tree #	Stem #	Species	GPS	Dia (cm)	Sector	Ht (m)	Remarks
1	1	*Lumnitzera littorea*	N05°50'01.9", E117°56'08.9"	13.0	1a		
2	2	*Rhizophora apiculata*	N05°50'02.0", E117°56'08.9"	13.2	1a		
3	3	*Scyphiphora hydrophyllacea*	N05°50'02.1", E117°56'08.9"	11.4	1a		
4	4	*Lumnitzera littorea*	N05°50'02.2", E117°56'09.2"	54.6	1a	28.2	
5	5	*Rhizophora apiculata*	N05°50'02.4", E117°56'08.9"	22.0	1a	12.5	
6	6	*Lumnitzera littorea*	N05°50'02.0", E117°56'09.0"	71.5	1a	28.9	
7	7	*Lumnitzera littorea*	N05°50'02.1", E117°56'09.0"	40.8	1a	26.1	
8	8	*Ceriops tagal*	N05°50'02.3", E117°56'09.1"	13.9	1a		unhealthy
9	9	*Ceriops tagal*	N05°50'01.9", E117°56'09.5"	12.7	1a		
10	10	*Ceriops tagal*	N05°50'01.9", E117°56'09.5"	10.1	1a		
11A	11	*Rhizophora apiculata*	N05°50'02.1", E117°56'09.8"	12.0	1a		multiple stems
11B	12	*Rhizophora apiculata*	N05°50'01.9", E117°56'09.7"	14.6	1a		multiple stems
12A	13	*Rhizophora apiculata*	N05°50'02.1", E117°56'09.8"	24.8	1b	14.8	multiple stems
12B	14	*Rhizophora apiculata*	N05°50'02.1", E117°56'09.8"	14.7	1b		multiple stems
12C	15	*Rhizophora apiculata*	N05°50'02.1", E117°56'09.8"	11.4	1b		
13	16	*Ceriops tagal*	N05°50'01.6", E117°56'09.5"	16.0	1b		
14	17	*Ceriops tagal*	N05°50'02.0", E117°56'09.5"	10.1	1b		
15	18	*Bruguiera sexangula*	N05°50'01.8", E117°56'09.4"	13.1	1b		
16	19	*Ceriops tagal*	N05°50'01.8", E117°56'09.5"	10.0	1b		
17A	20	*Rhizophora apiculata*	N05°50'02.1", E117°56'10.0"	15.7	1b		multiple stems
17B	21	*Rhizophora apiculata*	N05°50'02.1", E117°56'10.0"	20.2	1b	12.1	multiple stems
18	22	*Ceriops tagal*	N05°50'02.1", E117°56'10.0"	13.2	1b		
19	23	*Ceriops tagal*	N05°50'01.5", E117°56'09.6"	15.1	1b		
20	24	*Ceriops tagal*	N05°50'01.8", E117°56'09.8"	14.5	1b		
21	25	*Ceriops tagal*	N05°50'01.4", E117°56'09.6"	15.5	1b		
22	26	*Lumnitzera littorea*	N05°50'01.4", E117°56'09.3"	23.9	1b	17.1	
23	27	*Ceriops tagal*	N05°50'01.6", E117°56'09.3"	10.3	1b		
24	28	*Ceriops tagal*	N05°50'01.6", E117°56'09.3"	12.4	1b		
25	29	*Ceriops tagal*	N05°50'01.3", E117°56'09.5"	11.1	1b		
26	30	*Bruguiera sexangula*	N05°50'01.4", E117°56'09.3"	17.5	1b		
27	31	*Ceriops tagal*	N05°50'01.3", E117°56'09.5"	15.9	1b		
28	32	*Ceriops tagal*	N05°50'01.2", E117°56'09.2"	12.0	1b		
29	33	*Ceriops tagal*	N05°50'01.3", E117°56'09.2"	13.4	1b		
30	34	*Ceriops tagal*	N05°50'01.3", E117°56'09.3"	14.0	1b		
31	35	*Ceriops tagal*	N05°50'01.9", E117°56'08.9"	14.0	1c		
32	36	*Ceriops tagal*	N05°50'01.9", E117°56'08.9"	16.0	1c		
33	37	*Bruguiera sexangula*	N05°50'01.5", E117°56'09.7"	23.5	1c	15.5	
34	38	*Bruguiera sexangula*	N05°50'01.2", E117°56'09.7"	18.7	1c		
35	39	*Ceriops tagal*	N05°50'01.6", E117°56'09.2"	10.3	1c		
36	40	*Ceriops tagal*	N05°50'01.4", E117°56'09.2"	10.0	1c		
37	41	*Bruguiera sexangula*	N05°50'00.5", E117°56'09.2"	11.2	1c		
38	42	*Ceriops tagal*	N05°50'01.5", E117°56'09.3"	11.0	1c		
39	43	*Ceriops tagal*	N05°50'01.5", E117°56'09.3"	13.7	1c		
40	44	*Ceriops tagal*	N05°50'01.5", E117°56'09.3"	15.2	1c		
41	45	*Ceriops tagal*	N05°50'01.2", E117°56'09.2"	10.3	1c		
42	46	*Ceriops tagal*	N05°50'01.2", E117°56'09.2"	23.0	1c	14.2	
43	47	*Rhizophora apiculata*	N05°50'01.2", E117°56'09.0"	24.0	1c	13.8	
44	48	*Bruguiera sexangula*	N05°50'01.5", E117°56'09.0"	21.1	1c	14.9	
45	49	*Ceriops tagal*	N05°50'01.6", E117°56'09.0"	11.9	1c		
46	50	*Ceriops tagal*	N05°50'01.4", E117°56'09.1"	11.3	1c		
47	51	*Lumnitzera littorea*	N05°50'01.6", E117°56'09.3"	47.0	1c	25.7	
48	52	*Ceriops tagal*	N05°50'01.3", E117°56'08.9"	14.7	1c		
49	53	*Ceriops tagal*	N05°50'01.5", E117°56'08.7"	16.3	1c		
50	54	*Ceriops tagal*	N05°50'01.6", E117°56'08.6"	13.5	1c		
51	55	*Bruguiera sexangula*	N05°50'01.5", E117°56'08.9"	10.8	1c		
52	56	*Lumnitzera littorea*	N05°50'01.4", E117°56'08.7"	43.1	1d	24.5	
53	57	*Ceriops tagal*	N05°50'01.1", E117°56'08.6"	10.9	1d		
54	58	*Ceriops tagal*	N05°50'01.0", E117°56'08.5"	11.3	1d		
55	59	*Ceriops tagal*	N05°50'01.1", E117°56'08.9"	13.6	1d		
56	60	*Lumnitzera littorea*	N05°50'01.2", E117°56'08.8"	41.9	1d	24.8	
57	61	*Ceriops tagal*	N05°50'01.3", E117°56'09.0"	12.0	1d		
58	62	*Ceriops tagal*	N05°50'01.6", E117°56'08.7"	11.0	1d		
59	63	*Rhizophora apiculata*	N05°50'01.7", E117°56'08.9"	10.9	1d		
60	64	*Rhizophora apiculata*	N05°50'02.0", E117°56'09.1"	12.3	1d		
61	65	*Rhizophora apiculata*	N05°50'01.9", E117°56'08.7"	10.0	1d		

PLOT 2

Tree #	Stem #	Species	GPS	Dia (cm)	Sector	Ht (m)	Remarks
1	1	*Ceriops tagal*	N05° 50'03.6", E117° 56' 07.8"	14.5	2a		
2	2	*Ceriops tagal*	N05° 50'03.8", E117° 56' 07.3"	17.8	2a		
3	3	*Ceriops tagal*	N05° 50'03.5", E117° 56' 07.3"	11.6	2a		
4	4	*Ceriops tagal*	N05° 50'03.6", E117° 56' 07.2"	12.6	2a		
5	5	*Ceriops tagal*	N05° 50'03.8", E117° 56' 07.6"	11.8	2a		
6	6	*Rhizophora apiculata*	N05° 50'04.0", E117° 56' 07.7"	15.9	2a		
7	7	*Rhizophora apiculata*	N05° 50'04.0", E117° 56' 07.9"	16.2	2a		
8	8	*Ceriops tagal*	N05° 50'04.1", E117° 56' 07.9"	10.6	2a		
9	9	*Ceriops tagal*	N05° 50'03.9", E117° 56' 08.0"	17.3	2a		
10	10	*Rhizophora apiculata*	N05° 50'03.6", E117° 56' 07.9"	14.8	2a		
11	11	*Ceriops tagal*	N05° 50'03.7", E117° 56' 07.9"	13.9	2a		
12	12	*Rhizophora apiculata*	N05° 50'04.1", E117° 56' 07.7"	10.6	2a		
13	13	*Rhizophora apiculata*	N05° 50'03.8", E117° 56' 07.8"	16.2	2a		
14	14	*Ceriops tagal*	N05° 50'03.8", E117° 56' 07.6"	17.2	2a		
15	15	*Rhizophora apiculata*	N05° 50'03.9", E117° 56' 07.8"	12.6	2a		
16	16	*Ceriops tagal*	N05° 50'03.6", E117° 56' 07.7"	10.7	2a		
17	17	*Ceriops tagal*	N05° 50'03.5", E117° 56' 07.6"	16.7	2a		
18	18	*Ceriops tagal*	N05° 50'03.7", E117° 56' 08.1"	11.3	2a		
19	19	*Ceriops tagal*	N05° 50'03.9", E117° 56' 07.9"	23.0	2a	11.8	
20	20	*Ceriops tagal*	N05° 50'03.5", E117° 56' 08.0"	16.4	2a		
21	21	*Ceriops tagal*	N05° 50'03.8", E117° 56' 08.1"	11.2	2a		
22	22	*Ceriops tagal*	N05° 50'03.5", E117° 56' 08.0"	17.1	2a		
23	23	*Ceriops tagal*	N05° 50'03.7", E117° 56' 08.1"	24.0	2b	12.9	
24	24	*Ceriops tagal*	N05° 50'03.6", E117° 56' 07.8"	15.6	2b		
25	25	*Rhizophora apiculata*	N05° 50'03.2", E117° 56' 07.6"	16.7	2b		
26	26	*Rhizophora apiculata*	N05° 50'03.4", E117° 56' 07.9"	27.8	2b	12.4	
27	27	*Ceriops tagal*	N05° 50'03.6", E117° 56' 07.8"	11.5	2b		
28	28	*Ceriops tagal*	N05° 50'03.5", E117° 56' 07.8"	12.5	2b		
29	29	*Ceriops tagal*	N05° 50'03.3", E117° 56' 07.7"	17.5	2b		
30	30	*Ceriops tagal*	N05° 50'03.8", E117° 56' 07.7"	15.6	2b		
31	31	*Ceriops tagal*	N05° 50'03.3", E117° 56' 07.8"	14.5	2b		
32	32	*Rhizophora apiculata*	N05° 50'03.4", E117° 56' 07.7"	15.5	2b		
33	33	*Ceriops tagal*	N05° 50'03.4", E117° 56' 07.7"	11.4	2b		
34	34	*Ceriops tagal*	N05° 50'03.3", E117° 56' 07.4"	13.7	2b		
35	35	*Rhizophora apiculata*	N05° 50'03.5", E117° 56' 07.0"	17.4	2c		
36	36	*Lumnitzera littorea*	N05° 50'03.6", E117° 56' 06.7"	41.0	2c	27.3	
37	37	*Ceriops tagal*	N05° 50'03.6", E117° 56' 07.6"	12.6	2c		
38	38	*Ceriops tagal*	N05° 50'03.5", E117° 56' 07.6"	13.1	2c		
39	39	*Rhizophora apiculata*	N05° 50'03.8", E117° 56' 07.4"	18.7	2d		
40	40	*Ceriops tagal*	N05° 50'03.6", E117° 56' 07.0"	11.0	2d		
41	41	*Ceriops tagal*	N05° 50'03.7", E117° 56' 07.6"	11.5	2d		
42	42	*Ceriops tagal*	N05° 50'03.7", E117° 56' 07.5"	11.1	2d		
43	43	*Rhizophora apiculata*	N05° 50'03.7", E117° 56' 07.5"	19.7	2d		slanting position
44	44	*Ceriops tagal*	N05° 50'03.7", E117° 56' 07.6"	14.5	2d		
45A	45	*Rhizophora apiculata*	N05° 50'03.8", E117° 56' 07.4"	13.7	2d		multiple stems
45B	46	*Rhizophora apiculata*	N05° 50'03.8", E117° 56' 07.4"	19.8	2d		multiple stems
46A	47	*Rhizophora apiculata*	N05° 50'03.7", E117° 56' 07.4"	11.7	2d		multiple stems
46B	48	*Rhizophora apiculata*	N05° 50'03.7", E117° 56' 07.4"	19.3	2d		multiple stems
47	49	*Ceriops tagal*	N05° 50'04.0", E117° 56' 06.9"	10.2	2d		
48	50	*Ceriops tagal*	N05° 50'04.0", E117° 56' 07.0"	11.0	2d		
49	51	*Ceriops tagal*	N05° 50'04.1", E117° 56' 07.3"	13.3	2d		slanting position
50	52	*Rhizophora apiculata*	N05° 50'04.1", E117° 56' 07.4"	11.9	2d		
51	53	*Rhizophora apiculata*	N05° 50'04.4", E117° 56' 07.4"	10.9	2d		
52A	54	*Rhizophora apiculata*	N05° 50'04.4", E117° 56' 07.6"	14.6	2d		multiple stems
52B	55	*Rhizophora apiculata*	N05° 50'04.4", E117° 56' 07.6"	12.7	2d		multiple stems
52C	56	*Rhizophora apiculata*	N05° 50'04.4", E117° 56' 07.6"	15.2	2d		
53	57	*Ceriops tagal*	N05° 50'03.7", E117° 56' 07.1"	18.2	2d		

PLOT 3

Tree #	Stem #	Species	GPS	Dia (cm)	Sector	Ht (m)	Remarks
1	1	*Ceriops tagal*	N05°50' 06.1", E117°56' 05.9"	11.9	3a		
2	2	*Ceriops tagal*	N05°50' 06.2", E117°56' 06.2"	16.8	3a		
3	3	*Rhizophora apiculata*	N05°50' 05.6", E117°56' 05.3"	33.3	3a	19.2	
4	4	*Xylocarpus granatum*	N05°50' 06.3", E117°56' 05.9"	29.1	3a	13.6	slanting position
5A	5	*Rhizophora apiculata*	N05°50' 06.1", E117°56' 06.2"	13.8	3a		multiple stems
5B	6	*Rhizophora apiculata*	N05°50' 06.1", E117°56' 06.3"	14.8	3a		multiple stems
6	7	*Rhizophora apiculata*	N05°50' 06.2", E117°56' 06.4"	25.5	3a	19.0	
7	8	*Rhizophora apiculata*	N05°50' 06.0", E117°56' 06.6"	27.3	3a	16.2	
8	9	*Ceriops tagal*	N05°50' 05.5", E117°56' 05.9"	10.9	3b		
9	10	*Lumnitzera littorea*	N05°50' 05.5", E117°56' 05.9"	50.7	3b	23.3	
10	11	*Ceriops tagal*	N05°50' 05.5", E117°56' 05.9"	15.7	3b		
11	12	*Ceriops tagal*	N05°50' 06.1", E117°56' 06.1"	11.8	3b		
12	13	*Rhizophora apiculata*	N05°50' 05.8", E117°56' 05.7"	14.2	3b		
13	14	*Ceriops tagal*	N05°50' 05.9", E117°56' 06.3"	20.3	3b	13.9	
14	15	*Rhizophora apiculata*	N05°50' 05.6", E117°56' 06.0"	21.4	3b	15.4	
15	16	*Rhizophora apiculata*	N05°50' 05.8", E117°56' 05.6"	18.3	3b		
16	17	*Rhizophora apiculata*	N05°50' 05.8", E117°56' 05.6"	17.9	3b		
17	18	*Rhizophora apiculata*	N05°50' 05.7", E117°56' 05.2"	13.7	3b		slanting position
18	19	*Rhizophora apiculata*	N05°50' 05.5", E117°56' 06.3"	22.8	3b	17.8	
19A	20	*Rhizophora apiculata*	N05°50' 05.7", E117°56' 05.7"	18.9	3b		multiple stems
19B	21	*Rhizophora apiculata*	N05°50' 05.7", E117°56' 05.7"	22.7	3b	17.2	multiple stems
20	22	*Ceriops tagal*	N05°50' 05.4", E117°56' 05.4"	15.6	3c		
21	23	*Rhizophora apiculata*	N05°50' 05.5", E117°56' 05.6"	18.5	3c		
22	24	*Ceriops tagal*	N05°50' 05.6", E117°56' 05.4"	13.5	3c		
23	25	*Ceriops tagal*	N05°50' 05.9", E117°56' 04.9"	17.2	3c		
24	26	*Ceriops tagal*	N05°50' 05.6", E117°56' 05.6"	14.9	3c		
25	27	*Rhizophora apiculata*	N05°50' 06.1", E117°56' 05.7"	20.5	3c	18.4	
26	28	*Ceriops tagal*	N05°50' 06.1", E117°56' 05.0"	10.5	3c		
27	29	*Ceriops tagal*	N05°50' 05.7", E117°56' 05.6"	16.9	3c		
28	30	*Ceriops tagal*	N05°50' 05.8", E117°56' 05.6"	16.9	3c		
29	31	*Rhizophora apiculata*	N05°50' 05.9", E117°56' 05.2"	23.3	3c	22.6	
30	32	*Rhizophora apiculata*	N05°50' 05.8", E117°56' 05.8"	25.2	3c	19.7	
31	33	*Rhizophora apiculata*	N05°50' 05.9", E117°56' 04.9"	42.2	3c	21.1	
32	34	*Ceriops tagal*	N05°50' 06.3", E117°56' 05.2"	14.9	3d		
33	35	*Ceriops tagal*	N05°50' 06.3", E117°56' 05.2"	18.7	3d		
34	36	*Ceriops tagal*	N05°50' 06.2", E117°56' 06.2"	21.9	3d	16.5	
35	37	*Ceriops tagal*	N05°50' 06.2", E117°56' 05.6"	20.2	3d	16.0	
36	38	*Ceriops tagal*	N05°50' 06.0", E117°56' 05.7"	11.3	3d		
37	39	*Ceriops tagal*	N05°50' 06.0", E117°56' 04.8"	16.7	3d		
38	40	*Ceriops tagal*	N05°50' 05.9", E117°56' 05.2"	20.6	3d	12.5	
39	41	*Ceriops tagal*	N05°50' 05.9", E117°56' 05.2"	15.7	3d		
40	42	*Ceriops tagal*	N05°50' 06.2", E117°56' 04.7"	10.6	3d		
41	43	*Ceriops tagal*	N05°50' 06.2", E117°56' 04.8"	17.2	3d		
42	44	*Ceriops tagal*	N05°50' 05.9", E117°56' 05.4"	13.1	3d		
43	45	*Rhizophora apiculata*	N05°50' 06.2", E117°56' 05.5"	26.5	3d	18.4	
44	46	*Rhizophora apiculata*	N05°50' 06.5", E117°56' 05.3"	25.1	3d	15.1	

PLOT 4

Tree #	Stem #	Species	GPS	Dia (cm)	Sector	Ht (m)	Remarks
1	1	*Lumnitzera littorea*	N05°50' 08.2'', E117°56' 02.6''	69.0	4a	27.0	
2	2	*Ceriops tagal*	N05°50' 08.0'', E117°56' 02.3''	25.6	4a	13.5	
3	3	*Lumnitzera littorea*	N05°50' 08.0'', E117°56' 02.3''	35.0	4a	15.0	
4	4	*Ceriops tagal*	N05°50' 08.2'', E117°56' 02.4''	15.6	4a		
5	5	*Rhizophora apiculata*	N05°50' 07.9'', E117°56' 02.4''	10.7	4a		
6	6	*Rhizophora apiculata*	N05°50' 07.9'', E117°56' 02.3''	18.0	4b		
7A	7	*Rhizophora apiculata*	N05°50' 07.9'', E117°56' 02.3''	17.6	4b		multiple stems
7B	30	*Rhizophora apiculata*	N05°50' 07.9'', E117°56' 02.3''	12.8	4b		multiple stems
8	8	*Heritiera littoralis*	N05°50' 08.1'', E117°56' 02.3''	12.7	4b		
9	9	*Heritiera littoralis*	N05°50' 07.8'', E117°56' 02.3''	10.6	4b		
10	10	*Xylocarpus granatum*	N05°50' 08.0'', E117°56' 02.4''	35.7	4b	12.6	Broken top
11	11	*Rhizophora apiculata*	N05°50' 07.8'', E117°56' 02.6''	13.6	4b		
12A	12	*Rhizophora apiculata*	N05°50' 07.2'', E117°56' 02.7''	20.9	4b	15.4	
12B	28	*Rhizophora apiculata*	N05°50' 07.2'', E117°56' 02.7''	20.1	4b	19.3	
13	13	*Heritiera littoralis*	N05°50' 07.5'', E117°56' 02.4''	11.1	4b		
14	14	*Rhizophora apiculata*	N05°50' 07.7'', E117°56' 01.8''	21.1	4c	14.0	slanting position
15	15	*Rhizophora apiculata*	N05°50' 07.7'', E117°56' 01.8''	23.3	4c	18.4	
16	16	*Rhizophora apiculata*	N05°50' 07.2'', E117°56' 01.7''	28.1	4c	15.1	slanting position
17A	17	*Rhizophora apiculata*	N05°50' 07.6'', E117°56' 02.0''	16.8	4c		multiple stems
17B	29	*Rhizophora apiculata*	N05°50' 07.6'', E117°56' 02.0''	19.1	4c		multiple stems
18	18	*Heritiera littoralis*	N05°50' 07.6'', E117°56' 01.8''	27.1	4c	18.1	slanting position
19	19	*Bruguiera sexangula*	N05°50' 08.0'', E117°56' 02.1''	18.6	4c		
20A	20	*Rhizophora apiculata*	N05°50' 08.0'', E117°56' 02.0''	36.7	4d	13.5	multiple stems
20B	21	*Rhizophora apiculata*	N05°50' 08.0'', E117°56' 02.0''	31.9	4d	15.0	multiple stems
20C	22	*Rhizophora apiculata*	N05°50' 08.1'', E117°56' 02.3''	17.7	4d		multiple stems
21	23	*Lumnitzera littorea*	N05°50' 08.2'', E117°56' 02.0''	39.4	4d	18.4	
22	24	*Lumnitzera littorea*	N05°50' 08.3'', E117°56' 02.2''	12.3	4d		
23	25	*Lumnitzera littorea*	N05°50' 08.3'', E117°56' 02.3''	86.0	4d	30.6	
24	26	*Rhizophora apiculata*	N05°50' 08.3'', E117°56' 02.6''	13.8	4d		
25	27	*Rhizophora apiculata*	N05°50' 08.1'', E117°56' 02.6''	10.2	4d		

PLOT 5

Tree #	Stem #	Species	GPS	Dia (cm)	Sector	Ht (m)	Remarks
1	1	*Syzygium leucoxylon*	N05°50'08.5", E117°56'00.7"	12.9	5a		
2	2	*Heritiera littoralis*	N05°50'08.5", E117°56'00.7"	19.0	5a		
3	3	*Heritiera littoralis*	N05°50'08.6", E117°56'00.7"	22.3	5a	22.6	
4	4	*Pouteria obovata*	N05°50'08.5", E117°56'00.7"	21.2	5a	21.9	
5	5	*Heritiera littoralis*	N05°50'08.5", E117°56'00.9"	12.9	5a		
6	6	*Syzygium leucoxylon*	N05°50'08.2", E117°56'00.7"	11.4	5a		
7	7	*Heritiera littoralis*	N05°50'08.3", E117°56'01.0"	15.2	5a		
8	8	*Heritiera littoralis*	N05°50'08.3", E117°56'01.0"	10.2	5a		
9	9	*Heritiera littoralis*	N05°50'08.3", E117°56'00.9"	12.1	5a		
10	10	*Heritiera littoralis*	N05°50'08.3", E117°56'00.9"	12.8	5a		
11	11	*Heritiera littoralis*	N05°50'08.1", E117°56'00.8"	12.3	5a		
12	12	*Syzygium leucoxylon*	N05°50'08.0", E117°56'00.9"	13.0	5a		
13	13	*Heritiera littoralis*	N05°50'07.8", E117°56'00.8"	10.8	5b		
14	14	*Pouteria obovata*	N05°50'07.8", E117°56'00.8"	20.8	5b	22	
15	15	*Pouteria obovata*	N05°50'07.8", E117°56'00.8"	16.5	5b		
16	16	*Bruguiera sexangula*	N05°50'07.7", E117°56'00.9"	26.6	5b	19.7	
17	17	*Syzygium leucoxylon*	N05°50'07.7", E117°56'01.0"	18.5	5b		
18	18	*Bruguiera sexangula*	N05°50'07.4", E117°56'00.4"	39.2	5c	27.8	
19	19	*Syzygium leucoxylon*	N05°50'07.7", E117°56'00.5"	15.2	5c		
20	20	*Pouteria obovata*	N05°50'07.7", E117°56'00.4"	18.2	5c		
21	21	*Pouteria obovata*	N05°50'07.6", E117°56'00.4"	26.9	5c	19.9	
22	22	*Syzygium leucoxylon*	N05°50'07.7", E117°56'00.4"	11.9	5c		
23	23	*Bruguiera sexangula*	N05°50'07.7", E117°56'00.5"	25.9	5c	23.4	
24	24	*Bruguiera sexangula*	N05°50'07.7", E117°56'00.3"	37.4	5c	29	
25	25	*Bruguiera sexangula*	N05°50'07.6", E117°56'00.3"	34.8	5c	19.6	
26	26	*Bruguiera sexangula*	N05°50'07.6", E117°56'00.3"	30.2	5c	22.8	
27	27	*Bruguiera sexangula*	N05°50'07.6", E117°56'00.3"	30.8	5c	22.9	
28	28	*Syzygium leucoxylon*	N05°50'07.8", E117°56'01.0"	18.0	5c		
29	29	*Diospyros ferrea*	N05°50'07.8", E117°56'00.5"	13.5	5c		
30	30	*Syzygium leucoxylon*	N05°50'08.1", E117°56'00.5"	27.2	5d	15.1	
31	31	*Syzygium leucoxylon*	N05°50'08.2", E117°56'00.4"	12.0	5d		
32	32	*Syzygium leucoxylon*	N05°50'08.0", E117°56'00.3"	15.8	5d		
33	33	*Syzygium leucoxylon*	N05°50'08.0", E117°56'00.0"	10.4	5d		
34	34	*Syzygium leucoxylon*	N05°50'08.2", E117°56'00.4"	10.2	5d		
35	35	*Heritiera littoralis*	N05°50'08.3", E117°56'00.1"	20.2	5d	15.6	

Dead trees in the plots

Species	Dia (cm)	Ht (m)	Plot	Sector	GPS
Xylocarpus granatum	24.8	8.1	1	1b	N05°50'02.0", E117°56'09.7"
Ceriops tagal	17.1	8.7	1	1b	N05°50'02.0", E117°56'09.6"
Bruguiera sexangula	23.4	12.1	1	1b	N05°50'01.5", E117°56'09.6"
Ceriops tagal	12.5	7.2	1	1b	N05°50'01.5", E117°56'09.6"
Xylocarpus granatum	22.5	8.6	1	1d	N05°50'01.8", E117°56'09.1"
Xylocarpus granatum	29.3	4.1	2	2a	N05°50'03.6", E117°56'07.8"
Ceriops tagal	13.9	13.1	2	2a	N05°50'03.7", E117°56'07.8"
Xylocarpus granatum	16.7	13	2	2a	N05°50'03.6", E117°56'07.7"
Xylocarpus granatum	20.6	8.1	2	2b	N05°50'03.2", E117°56'07.6"
Xylocarpus granatum	36.7	15	2	2b	N05°50'03.1", E117°56'07.8"
Xylocarpus granatum	23.3	13.5	2	2c	N05°50'03.7", E117°56'07.4"
Ceriops tagal	22.2	6.3	3	3c	N05°50'05.1", E117°56'05.6"
Ceriops tagal	21.3	11.6	3	3d	N05°50'06.2", E117°56'06.3"
Heritiera littoralis	20.6	13.7	5	5d	N05°50'08.1", E117°56'00.1"

Appendix II. Family Composition.

Plot No	Family	Stem Density /ha	Basal Area /ha	Rel. Density	Rel. Basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
1	Combretaceae	114.3	18.3	12.3	57.3	34.8	14.3	14.3		57.1	14.3		14.3	
	Rhizophoraceae	800.0	13.5	86.2	42.2	64.2	700.0	100.0						
	Rubiaceae	14.3	0.1	1.5	0.5	1.0	14.3							
	Total	928.6	31.9	100.0	100.0	100.0	728.6	114.3		57.1	14.3		14.3	

Plot No	Family	Stem density /ha	Basal Area /ha	Rel. Density	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
2	Combretaceae	14.3	1.9	1.8	11.5	6.6				14.3				
	Rhizophoraceae	800.0	14.6	98.2	88.5	93.4	757.1	42.9						
	Total	814.3	16.5	100.0	100.0	100.0	757.1	42.9		14.3				

Plot No	Family	Stem density /ha	Basal Area /ha	Rel. Density	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
3	Combretaceae	14.3	2.9	2.2	12.6	7.4					14.3			
	Meliaceae	14.3	0.9	2.2	4.2	3.2		14.3						
	Rhizophoraceae	628.6	19.0	95.7	83.2	89.4	400.0	200.0	14.3	14.3				
	Total	657.1	22.8	100.0	100.0	100.0	400.0	214.3	14.3	14.3	14.3			

Plot No	Family	Stem density /ha	Basal Area /ha	Rel. Density	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
4	Combretaceae	71.4	16.9	16.7	57.9	37.3	14.3		28.6			14.3		14.3
	Malvaceae	57.1	1.3	13.3	4.3	8.8	42.9	14.3						
	Meliaceae	14.3	1.4	3.3	4.9	4.1			14.3					
	Rhizophoraceae	285.7	9.6	66.7	32.9	49.8	171.4	85.7	28.6					
	Total	428.6	29.2	100.0	100.0	100.0	228.6	100.0	71.4			14.3		14.3

Plot No	Family	Stem density /ha	Basal Area /ha	Rel. Density	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
5	Ebenaceae	14.3	0.2	2.9	1.2	2.0	14.3							
	Malvaceae	128.6	2.4	25.7	13.5	19.6	100.0	28.6						
	Myrtaceae	185.7	3.5	37.1	19.7	28.4	171.4	14.3						
	Rhizophoraceae	100.0	8.3	20.0	47.3	33.7		28.6	71.4					
	Sapotaceae	71.4	3.2	14.3	18.2	16.3	28.6	28.6	14.3					
	Total	500.0	17.5	100.0	100.0	100.0	314.3	100.0	85.7					

Appendix III. Species Composition.

Plot No	Species	Stem density /ha	Basal Area /ha	Rel. Dens -ity	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
1	*Bruguiera sexangula*	100.0	2.3	10.8	7.3	9.0	71.4	28.6						
	Ceriops tagal	514.3	7.2	55.4	22.4	38.9	500.0	14.3						
	Lumnitzera littorea	114.3	18.3	12.3	57.3	34.8	14.3	14.3		57.1	14.3		14.3	
	Rhizophora apiculata	185.7	4.0	20.0	12.6	16.3	128.6	57.1						
	Scyphiphora hydrophyllacea	14.3	0.1	1.5	0.5	1.0	14.3							
	Total	928.6	31.9	100.0	100.0	100.0	728.6	114.3		57.1	14.3		14.3	

Plot No	Species	Stem density /ha	Basal Area /ha	Rel. Dens -ity	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
2	*Ceriops tagal*	500.0	8.3	61.4	50.7	56.0	471.4	28.6						
	Lumnitzera littorea	14.3	1.9	1.8	11.5	6.6				14.3				
	Rhizophora apiculata	300.0	6.2	36.8	37.9	37.4	285.7	14.3						
	Total	814.3	16.5	100.0	100.0	100.0	757.1	42.9		14.3				

Plot No	Species	Stem density /ha	Basal Area /ha	Rel. Dens -ity	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
3	*Ceriops tagal*	342.9	6.8	52.2	29.9	41.0	285.7	57.1						
	Lumnitzera littorea	14.3	2.9	2.2	12.6	7.4					14.3			
	Rhizophora apiculata	285.7	12.2	43.5	53.3	48.4	114.3	142.9	14.3	14.3				
	Xylocarpus granatum	14.3	0.9	2.2	4.2	3.2		14.3						
	Total	657.1	22.8	100.0	100.0	100.0	400.0	214.3	14.3	14.3	14.3			

Plot No	Species	Stem density /ha	Basal Area /ha	Rel. Dens -ity	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
4	*Bruguiera sexangula*	14.3	0.4	3.3	1.3	2.3	14.3							
	Ceriops tagal	28.6	1.0	6.7	3.4	5.1	14.3	14.3						
	Heritiera littoralis	57.1	1.3	13.3	4.3	8.8	42.9	14.3						
	Lumnitzera littorea	71.4	16.9	16.7	57.9	37.3	14.3		28.6			14.3		14.3
	Rhizophora apiculata	242.9	8.2	56.7	28.1	42.4	142.9	71.4	28.6					
	Xylocarpus granatum	14.3	1.4	3.3	4.9	4.1			14.3					
	Total	428.6	29.2	100.0	100.0	100.0	228.6	100.0	71.4			14.3		14.3

Plot No	Species	Stem density /ha	Basal Area /ha	Rel. Dens -ity	Rel. basal Area	Rel. Domi -nance	Diameter Class (cm)							
							10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
5	*Bruguiera sexangula*	100.0	8.3	20.0	47.3	33.7		28.6	71.4					
	Diospyros ferrea	14.3	0.2	2.9	1.2	2.0	14.3							
	Heritiera littoralis	128.6	2.4	25.7	13.5	19.6	100.0	28.6						
	Pouteria obovata	71.4	3.2	14.3	18.2	16.3	28.6	28.6	14.3					
	Syzygium leucoxylon	185.7	3.5	37.1	19.7	28.4	171.4	14.3						
	Total	500.0	17.5	100.0	100.0	100.0	314.3	100.0	85.7					

Effect of different rooting media on stem cuttings of *Eucalyptus pellita* F. Muell

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Abstract. The use of woody stem cuttings as propagation material is vital when seeds are insufficient and when producing clonal material. The objectives of this study were to determine the survival rate and rooting ability of *Eucalyptus pellita* stem cuttings from different portions of the stem and using different rooting media. Three portions of stem cutting (apical, median and basal) at 5 to 10 cm length were obtained from three-month-old *E. pellita* seedlings. Each stem cutting contained two trimmed apex leaves, and then rooting hormone (IBA) was applied as a root booster. Three rooting media were used, namely river sand, black soil and coco peat. The experiments consisted of 3 treatments and 3 replications. Data were collected bi-weekly for 14 weeks. The assessment for rooting ability was performed after four weeks of planting. The result obtained showed river sand is the best rooting media and apical part as the most suitable part to be propagated.

Keywords: *Eucalyptus pellita,* stem cuttings, rooting media

INTRODUCTION

Eucalyptus pellita F. Muell, commonly known as red mahogany, is a tree species belonging to the family of Myrtaceae (Dombro 2010). *E. pellita* is a fast growing species and can adapt to a wide range of environment including variable climatic and topographic conditions. It is a highly pest and disease resistant species, has good coppicing ability and has wide utilization, such as for making pulp and paper, sawn timber, building construction, heavy construction, furniture, plywood, boat and others (Orwa *et al*. 2009). These make it an attractive and ideal species for tree plantations (Doran & Turnbull 1997). Owing to the increasing global pulp and paper demand, *E. pellita* is significant in becoming the raw materials for pulp and paper products (Dombro 2010, Pirralho *et al*. 2014), and has been introduced as one of the recommended fast growing species planted on a large scale commercially (Irianto 2009). The high potential of *E. pellita* as a commercial forest plantation justifies research efforts, such as vegetative stem cutting propagation. Therefore, stem cutting was introduced to sustainably produce *Eucalyptus* species planting materials (Wendling & Xavier 2005).

Stem cutting is widely used for propagating commercial forest tree species where large number of cuttings can be obtained from seedlings as mother/stock plants (Vyn Wyk 1997). The stem cutting is one of the most suitable and economical methods for propagating woody plants especially at the early stage of seedling including *Eucalyptus* species (Wendling & Xavier 2005). To increase the sources of planting materials as well as to increase the plantation of *E. pellita,* propagation through stem cutting by using selected seedlings can be most cost-effective while maintaining both quality and quantity. The objectives of this study were to determine the survival rate and to investigate the rooting ability of *E. pellita* cuttings with different parts of stem cuttings and different rooting media.

MATERIALS AND METHODS

This study was carried out for four months at the nursery of the Forestry Complex, Faculty of Science and Natural Resources, Universiti Malaysia Sabah. The stock plants or seedlings of *E. pellita* at 3 month-old were obtained from the nursery of Sabah Forest Industries Sdn. Bhd. which is located at Sipitang, Sabah. Randomized complete block design was used which consists of three rooting media (river sand, black soil and coco peat), with three replicates. Each of the three experiments consists of 3 treatments (apical, median and basal) and 3 replications. Each treatment and replication consisted of 6 stem cuttings. Therefore, for each experiment, there were 3 lines of blocks (Tray) that consisted of 9 plots that was divided into 54 stem cuttings accordingly to the treatment and replication. The potting tray consisted of 96 beds. In this condition, 54 parent plants of *E. pellita* were used to prepare a total of 162 cuttings. A propagator was built and was covered with the transparent polythene sheet to maintain high air humidity within the propagator. Then, the propagator was shaded by using a black plastic netting to protect against direct sunlight (Aminah *et al*. 1995).

Each seedling was about 25 to 30 cm in height at 3-month-old. The stem was cut into 3 parts which were the apical part, median part and basal part and then placed into three different bucket of clear water to maintain water content. For the position of the stem cutting, it was located at approximately 1 cm above the node and approximately 1 cm below the node. The length of each cutting was 5 to 10 cm (Murugan 2007). For the apical part, the first node was excluded as undeveloped apical shoots are not suitable for cutting development (Aminah *et al*. 1995). For each part of the cuttings, only two apex leaves were left. Two over three of leaves were trimmed using cutter to reduce water loss through transpiration during rooting period (Ajik & Kimjus 2006). The number of node on each cutting depends on the parent stem as all leaves below the apex were removed.

Three media namely, river sand, black soil and coco peat were treated with Thiram (80% w/w), an ectoparasiticide to prevent fungus and parasite growth in the rooting media. River sand was used as control media. One end of the cutting was dipped into clear water and then 0.5 cm into the rooting hormone (IBA) for 5 seconds, air-dried for 10 seconds before inserting into the rooting medium (Yeboah *et al*. 2010). The stem cuttings were inserted one-third to one-half their length into the rooting medium (Evans & Blazich 1999) without bending. The cuttings were placed into a propagator and were watered manually on daily basis. Data was collected bi-weekly for 14 weeks. The assessment for rooting ability was performed after four weeks. Survival rate, rooting ability and correlation between the numbers of root and the height of the shoots were performed. Analysis of variance (ANOVA) was used for the mean comparison.

RESULTS

Table 1 shows the survival rate, mean height of shoots and number of roots of *E. pellita* seedlings by stem cuttings treated with different rooting media. Based on two-way ANOVA, the result shows that there were no significant differences (p>0.05) between different stem parts and between different media.

Table 1. Growth performance of *E. pellita* stem cuttings in different rooting media.

Rooting Media	Cutting Parts	No. of Cuttings	Survival Rate % (no. rooted)	Mean Height of Shoots (cm)	Mean No. of Roots
River Sand	Apical	18	44	7.16 (2.20)	16 (3.39)
	Median	18	50	7.57 (2.11)	18 (2.40)
	Basal	18	28	9.66 (2.21)	16 (2.35)
Black Soil	Apical	18	11	6.98 (2.35)	13 (3.40)
	Median	18	0	-	-
	Basal	18	0	-	-
Coco Peat	Apical	18	61	7.13 (2.01)	9 (2.01)
	Median	18	0	-	-
	Basal	18	0	-	-

Note: Mean values were no significant different at p<0.05; the values in parentheses represent standard deviation.

Mortality rate of cuttings was the lowest in river sand as compared to top soil and coco peat medium (Table 1). Every part of the cuttings in river sand medium showed survival whereas the lowest total mortality rate was the median part with 50%. Therefore, the survival rate was 44%, 50% and 28% for apical, median and basal part respectively. In terms of different cuttings, the apical part showed the best survival in all media with the highest rate in coco peat (61%).

The rooting ability was based on the number of cuttings that rooted and the number of root per cutting. There was no rooting for the median and basal parts in the black soil as well as coco peat rooting media. However, in river sand, different stem parts produced roots with similar average number of rooted cuttings. The median parts in river sand had the highest number of rooted cuttings. The overall percentage of rooted cutting was 42.6%, 3.7% and 24.1% in river sand, black soil and coco peat respectively.

Based on Figures 1 and 2, there was no rooting for cuttings consisting median and basal parts in black soil and coco peat media. In river sand all three types of cuttings were rooted; however, only the apical part was rooted in all rooting media. The highest number of roots (18 roots) was from the median part in river sand media whereas the lowest number of roots (9 roots) was from the apical part in coco peat (Figure 1). The tallest shoot (9.7cm) came from the basal part that was rooted in river sand media whereas the shortest shoot (7.0cm) was from the apical part in black soil media (Figure 2). This study indicated that in river sand, all types of cuttings showed good rooting as compared to the other rooting media.

Based on the correlation analysis, there was a significantly strong positive correlation between the number of roots and the height of the shoots of apical part in river sand, black soil and coco peat rooting media with r-value of $r = 0.775$; $p<0.01$, $r = 0.993$; $p<0.01$ and $r = 0.717$; $p<0.01$ respectively. The correlation was done only on apical part because only apical part was rooted in all rooting media.

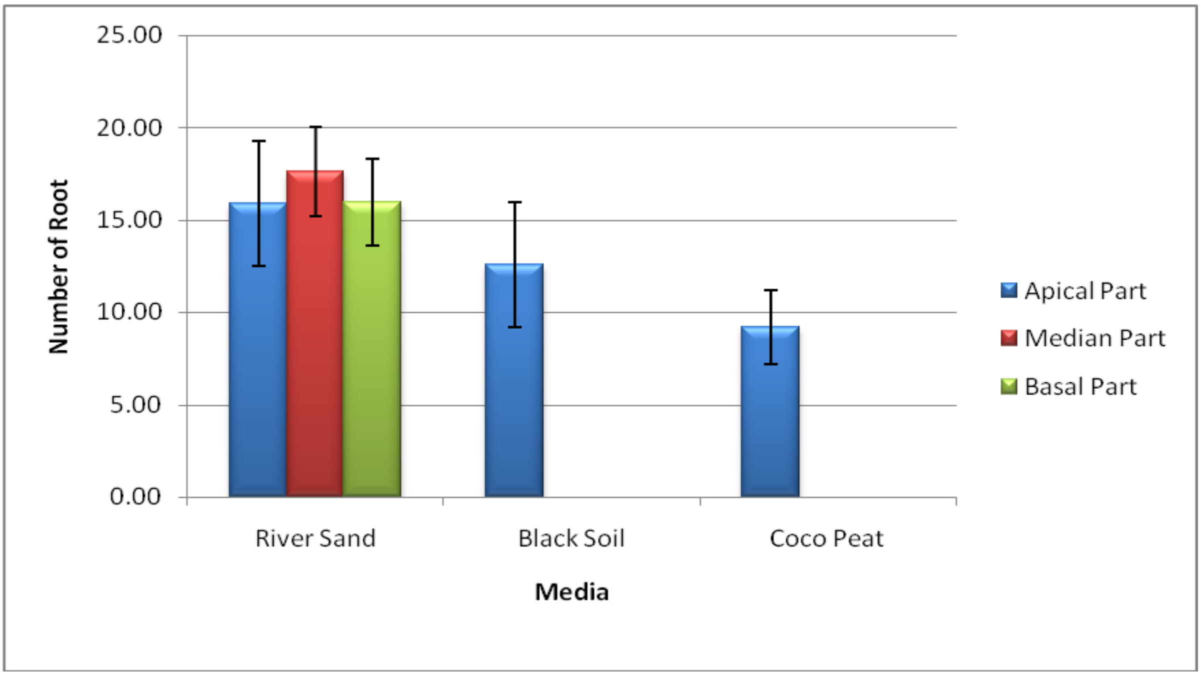

Figure 1. The average number of roots for cuttings in different rooting media.

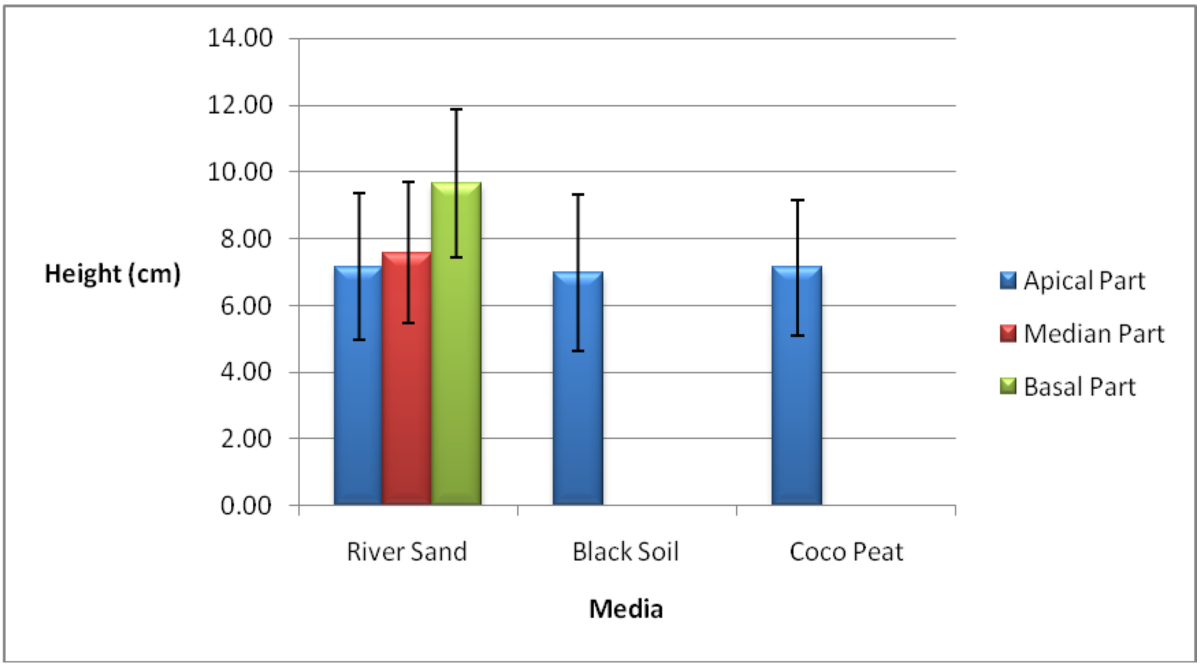

Figure 2. The average height of shoot growth based on different rooting media.

DISCUSSION

Rooting media are recognized as one of the most important factors that influence the inducement of rooting from stem cuttings. The physical properties of rooting media, such as total porosity, bulk density, air space, water holding capacity and available water content will affect the water and air supplement to their growth (Baiyeri 2005). The growth and development of cuttings based on aeration and moisture content of the substrate are the major factors that will affect the emergence of roots and bring effect on root quality (Leakey *et al*. 1990). River sand has high aeration porosity with about 30% and within the range of 25 to 35% of aeration porosity which is the ideal and optimal rooting and growth condition (Amri *et al*. 2009). Sand fulfills the characteristic of providing sufficient porosity which is able to give adequate oxygen availability. Oxygen availability refers to the supplying of the oxygen to the growth and it plays an important role for the development of rooting system. To this, the suitable rooting medium like river sand is ideal for root respiration because it has the optimal volume of gas filled pore space and oxygen diffusion rate (Fonteno & Nelson 1990). Thus, as observed in this study, cuttings from different parts of the stem that were rooted in river sand showed good survival rate and rooting as compared to those grown in black soil and coco peat media.

The second main aspect is water-holding capacity. The range of the optimal rooting and growth condition of easily available water is within 20 to 30% (Verdonck *et al*. 1983). The water-holding capacity of river sand is 28.3%, and it is an ideal characteristic to induce roots and prevent mortality (Amri *et al.* 2009). As cuttings take up water poorly through the base of the stem until adventitious roots are formed, sufficient moisture content and good drainage are important factors. Types of rooting media that retained too much or too little moisture will give poor rooting ability of the cuttings (Copes 1977). The poorest result of the cutting survival was that grown in black soil with only 3.7% survival out of the total 54 cuttings. Black soil is classified as a high fertility medium consisting of high amount of Calcium and Magnesium Carbonate (Basu 2011). High fertility of the rooting medium is not necessarily beneficial as it damages new roots and inhibits growth (Relf & Ball 2009). Furthermore, soil tends to consist of sand, clay and slit which have low percentage of aeration porosity (Amri *et al*. 2009), that could lead to high mortality of cuttings. Results from this study corresponded to results from other studies on propagation of stem cuttings of *E. pellita* in different rooting media whereby river sand was also shown to be the best rooting medium (Amri *et al.* 2009).

Another aspect to consider is that the apical part has a better rooting ability attributed to the presence of high amount of auxin production. The presence of auxin in this portion of the stem leads to the emergence of roots, thereby indicating the important role of this hormone in the enhancement of rooting and growth (Dela Cruz 1998). The strong relationship indicated that the higher the number of the roots, the taller the height of the developing shoots. The main reason causing this strong relationship is due to the role played by the roots. The roots are the vascular system that was developed in the roots function as to transport water and minerals from the root to the leave or to the top such as shoots (Lee 2004), and the dependent of the shoots to roots are higher (Kramer & Boyer 1995). If there are more roots working on transporting mineral, it means that there are more mineral absorbed that will enhance more growth of the shoots.

CONCLUSION

The ideal and suitable rooting media is river sand. The cuttings that survived in river sand had good rooting ability and positive growth. The best cutting came from the apical part of the stem and was able to survive and root in all three different media. Among these, river sand is the best rooting medium to produce a good number of roots and provide good development of shoots of *E. pellita* cuttings.

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Insect diversity as a tool to monitor the status of a rehabilitated mangrove site in Sabah

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Abstract. Insect diversity was used as a tool to monitor status of the Sg. ISME site in Sandakan, Sabah. The site was a degraded mangrove area but was rehabilitated and planted with mangrove species in 2012 through a collaborative project among the Sabah Forestry Department, International Society for Mangrove Ecosystems (ISME) and Tropical Biosphere Research Center (TBRC) of Ryukyus University, Japan. Nocturnal insect diversity monitored through light-trapping has been conducted for three years since 2015. Insect diversity indices (Shannon Wiener, Simpson and Fisher Alpha) as well as species richness and abundance were used to monitor the environmental status of Sg. ISME site. In general, there is an improvement from the perspective of insect fauna. When compared with other forested sites, however, the insect diversity in Sg. ISME is still relatively low. Besides nocturnal insects, diurnal insects were also documented through sweep nets and forceps. The insect data serve as baseline information for future research work on mangrove rehabilitation as well as to strengthen the ongoing collaborative research among the relevant agencies on tropical mangrove ecosystems.

Keywords: insect diversity, rehabilitated mangrove, light-trapping, sweep net

INTRODUCTION

Traditionally, mangroves have been a forgotten ecosystem neglected by both scientists and administrators. Due to their harsh environment, they have been considered as wasteland and have always been an undervalued resource (Field 1995 & Nilus *et al*. 2010). However, over time, humans began to appreciate the many ecological services and goods provided by this type of swamp forests (Clough 2013, Ong & Gong 2013, Baba *et al*. 2013).

Malaysia accounts for about 3.7% of the world's mangrove area and Sabah disproportionately accounts for 59% (341,000 ha) of the country's total. About 96% are gazetted as forest reserves, under the jurisdiction of the Sabah Forestry Department (Tangah *et al*. 2015 & Nilus *et al*. 2010). The mangroves in Sabah occur mainly along the east coast where the towns of Sandakan, Lahad Datu and Tawau are located.

Although there are still vast areas of mangrove forests in Sabah, they are under increasing pressures for socio-economic development, such as conversion to aquaculture, agriculture and urban land uses. All these would adversely affect the mangrove diversity

(Latiff 2005). To date, some 3,300 ha of mangrove forest reserves in Sabah have been illegally encroached and exploited (Tangah *et al*. 2015).

Realizing that mangroves are important natural resources, efforts have been made to manage them in accordance with the principles of conservation and sustainable use. Hence, in 2011, the Sabah Forestry Department (SFD) initiated a collaborative project with the International Society for Mangrove Ecosystems (ISME) on mangrove rehabilitation, with funding from Tokio Marine & Nichido Fire Insurance Co., Ltd. In the first phase (2011-2014), a total of 151.5 ha of degraded mangroves were rehabilitated. The collaboration is in its second phase now (2014-2019), with a targeted planting area of 200 ha (Tangah *et al*. 2017). For the research component, the project involves the participation of researchers from Tropical Biosphere Research Center (TBRC) of Ryukyus University, Japan.

Insects are often used in environmental studies as bioindicators due their diversity, abundance and close relationship with the biotic and abiotic factors in the environment. They can indicate the effects of habitat changes and fragmentation, and the effectiveness of management schemes designed to preserve or change individual species- or community-level patterns (Chung 2013). Insect diversity has been used as a tool to indicate the status of the surveyed area, and to compare with other forested sites in Sabah, e.g. Chung *et al*. (2013 & 2016). Mangrove insects, however, have remained a neglected field in many parts of the world (Mitra *et al*. 2017).

STUDY AREA & PURPOSE OF STUDY

Sungai ISME (N 05^{0}59’36.2”, E 118^{0}01’06.1”) is one of the case study sites established through the collaboration between SFD and ISME on rehabilitation of mangroves in Sabah. It is a 2-ha site in Sandakan (Figure 1), previously encroached with oil palms but rehabilitated with mangrove species in 2012. The planted species are *Rhizophora apiculata*, *R. mucronata*, *Ceriops tagal*, *Terminalia catappa*, *Avicennia alba* and *Bruguiera cylindrica*. It was officially named Sg. ISME by SFD, honouring the involvement of the society in mangrove rehabilitation in Sabah (Tangah *et al*. 2015).

The purpose of this ongoing study is to monitor the status of the environment using insect diversity as an indicator. It is also meant to procure some basic information on insects found within this study site, as no insect study was conducted previously. Thus far, insect diversity survey has been conducted in 2015, 2016 and 2017. The data will serve as baseline information for future research. As the site is scientifically important for the collaboration among SFD, ISME and TBRC, such data will provide supporting information on mangrove rehabilitation. It will potentially generate interest among other groups either local or international, to work or conduct research in this case study site.

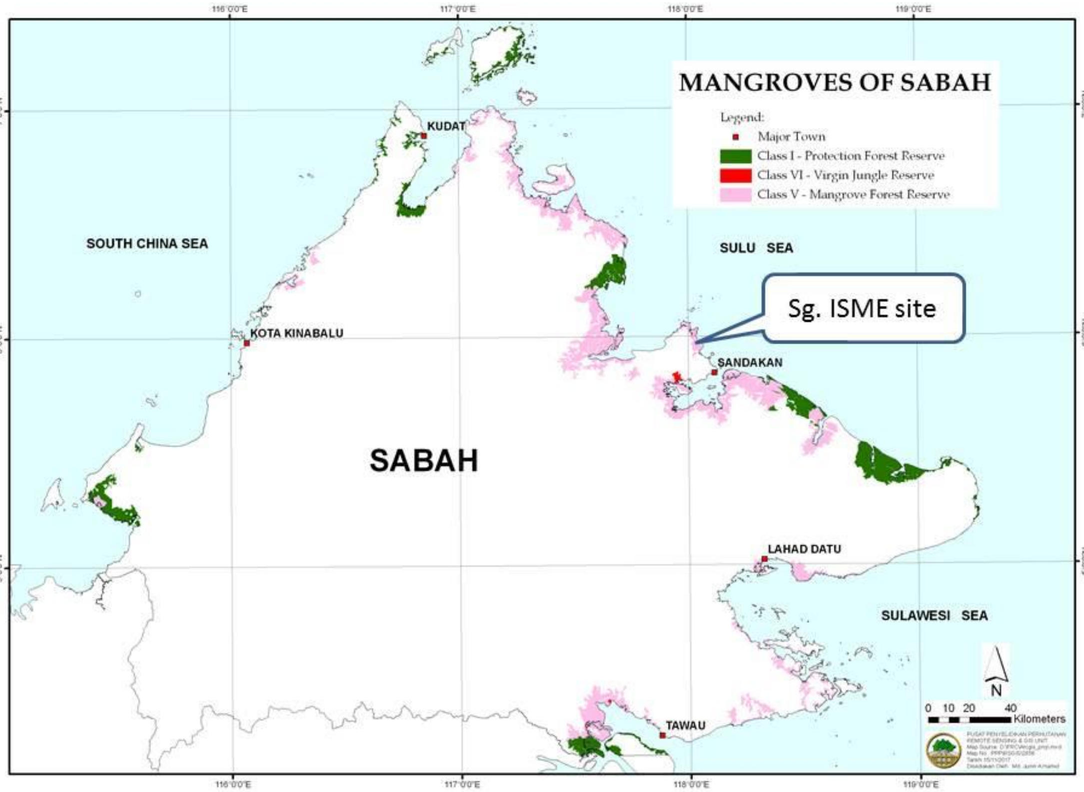

Figure 1. The distribution of mangrove vegetation (forest reserves) in Sabah and the location of Sg. ISME study site in Sandakan. The Mangrove Forest Reserves (Class V) are purple in colour while some were gazetted as Protection Forest Reserves (Class I), in green and Virgin Jungle Reserves (Class VI) in red. There is also a small reserve, Nabahan FR (356 ha), classified as Amenity Forest Reserve (Class IV) in western Sabah.

MATERIALS & METHODS

Light trap was used to sample nocturnal insects while sweep nets and forceps were used to sample diurnal insects.

Light trap

The trap consisted of a vertical white sheet (2 X 2 m) illuminated by a 250W mercury-lithium bulb, powered by a 230V Yamaha generator. The trap was set up at different locations facing the study area, from 7:00 to 8:30 p.m. A GPS (Model: Garmin GPSMAP 60CSx) was used to determine the coordinates of each sampling site. Temperature and humidity were taken with a digital hygrometer from Extech Instruments (model no. 445702).

Table 1. Sampling dates at Sg. ISME site from 2015 to 2017 and the mean temperature and humidity during light-trapping.

Sampling date	Mean temperature (°C)	Mean humidity (%)
23-25 March, 2015	26.1	81.7
16-18 February, 2016	27.6	77.7
4-6 April, 2016	28.3	74.3
8-10 August, 2017	25.2	87.7

To evaluate diversity of the sampling area, insect species and individuals (≥ 5 mm) within the 1 X 1 m square of the white cloth were enumerated from 8:00 to 8:30 pm. This is a rapid biodiversity assessment method because by the end of the sampling time, species and individual numbers can be obtained, and the data can be used to calculate diversity indices, i.e. Shannon Wiener, Simpson and Fisher Alpha, using the Species Diversity & Richness version IV (SDR 2006). This method is simple, fast and can be carried out by non-insect specialist. To avoid compounding human error, the same staff was assigned to count the species and individual numbers throughout the sampling period, and also for other sampling sites. Light-trapping sites are shown in Table 2.

Table 2. Light-trapping at different locations within Sg. ISME site. The same spots were used from 2015 to 2017.

Sampling site	Coordinates	Elevation (m)
A	N05°59'36.2" E118°01'02.6"	14
B	N05°59'36.2" E118°01'04.0"	16
C	N05°59'36.2" E118°01'06.0"	7

Sweep net and manual collection

Sweep nets were used to collect flying insects while other insects were sampled using fine forceps. Butterflies and dragonflies were put in triangle papers while other specimens were put in vials with 75% ethanol solution. Sampling was conducted within the site from morning until noon time.

Insect specimens and identification

In this survey, focus was given to certain insect groups, i.e., butterflies, moths and beetles. Only interesting and potential indicator insect species were sampled. Photographs were taken to facilitate identification.

Selected specimens were dry-mounted and sorted to family and some to the genus and species level. The specimens sampled from this survey are deposited at the Forest Research Centre, Sepilok, Sabah. Dry-mounted specimens were identified based on the FRC Entomology Collection and various reference materials, e.g. Otsuka (1988 & 2001) and Kirton (2014) for butterflies; Holloway (1983, 1985, 1986, 1988, 1989, 1993, 1996, 1997, 1998a & b, 1999, 2001, 2003, 2005, 2008, 2009 & 2011), Robinson *et al.* (1994) and Sutton *et al*. (2015) for moths; Fujita (2010), Makihara (1999) and Tung (1983) for beetles; Orr (2003) and Tang *et al*. (2010) for dragonflies and damselflies. Some other insects were identified based on Hill and Abang (2005). Insect expert, i.e. Dr Steven Bosuang, Dr Roger Kendrick and Dr Terry Whittaker assisted in the identification of some insects. Unidentified specimens were morphotyped.

Diversity indices

The diversity indices, namely Shannon Wiener, Simpson and Fisher Alpha were calculated through a diversity analysis software developed by Seaby and Henderson (2007), based on Magurran (2004), and Southwood and Henderson (2000).

Shannon Wiener Index (H')

This index is calculated in the following way:

$$H' = -\sum p_i \ln p_i$$

where p_i is the proportion of individuals found in species i. For a well-sampled community, we can estimate this proportion as $p_i = n_i/N$, where n_i is the number of individuals in species i and N is the total number of individuals in the community. Since by definition the p_is will all be between zero and one, the natural log makes all of the terms of the summation negative, which is why we take the inverse of the sum. Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon index increases as both the richness and the evenness of the community increase.

Simpson Index (D)

This index is based on the probability of any two individuals drawn at random from an infinitely large community belonging to the same species:

$$D_s = \sum p_i^2$$

where again p_i is the proportion of individuals found in species i. For a finite community, this is

$$D = \sum n_i(n_i - 1)/N(N - 1)$$

D is a measure of dominance, so as D increases, diversity (in the sense of evenness) decreases. Thus, Simpson's index is usually reported as its complement 1-D (or sometimes 1/D or –lnD). Since D takes on values between zero and one and approaches one in the limit of a monoculture, (1-D) provides an intuitive proportional measure of diversity that is much less sensitive to species richness.

Fisher Alpha Index (S)

This is a parametric index of diversity that assumes that the abundance of species follows the log series distribution:

$\alpha x, \alpha x^2/2, \alpha x^3/3, \ldots \alpha x^n/n$

where each term gives the number of species predicted to have 1,2,3,....n individuals in the sample. The index is the alpha parameter. This is a useful index, which has been widely used. It is estimated by an iterative procedure that may take an appreciable amount of time with large data sets.

RESULTS & DISCUSSION

Nocturnal insect diversity

When the nocturnal insect species richness is compared with previous data recorded, the sampling in August 2017 appears to be the highest, as shown in Figure 2a. It shows an increase in species number from the previous number of species recorded. The lowest species richness recorded was in February 2016 due to the degradation of the adjacent oil palm habitat in which many of the trees died as a result of seawater influx as well as the unexpectedly hot weather during that period. Then, it shows an increase in the number of species recorded until August 2017. In terms of nocturnal number of individuals and insect diversity (Shannon, Simpson and Fisher Alpha indices) in Sg. ISME, the values are also the highest in August 2017 sampling (Figures 2b-2e), compared to the previous data recorded. The variation (as indicated by standard deviation), however, in most of the sampling periods is still very high which shows that the nocturnal insect community within the microhabitats in Sg. ISME is still not stable and fluctuating. It is hoped that such variation will reduce after a much longer period of ecological succession within the site.

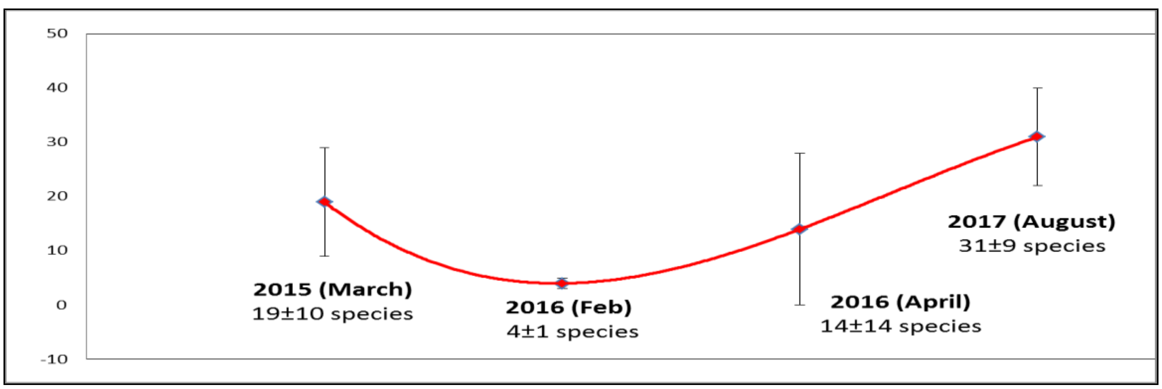

Figure 2a. Species number (±standard deviation) within one square metre as assessed through light-trapping in Sg. ISME site.

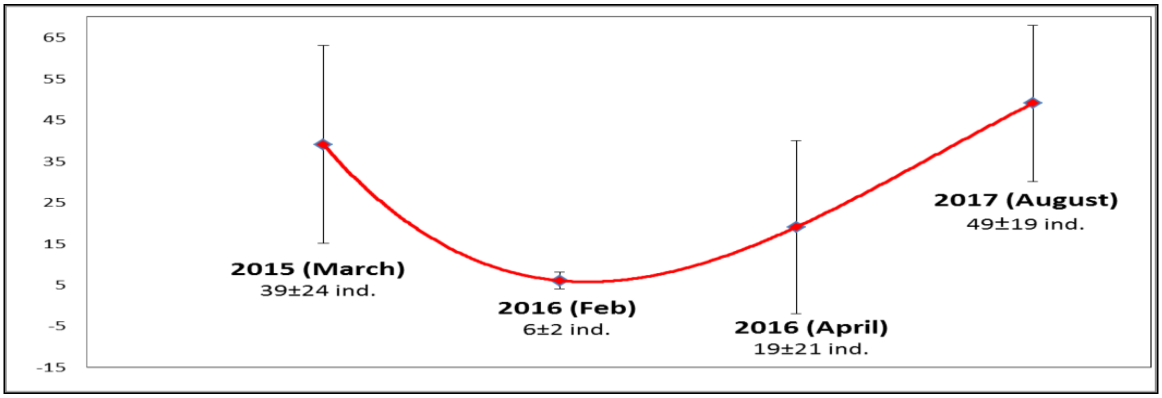

Figure 2b. Number of individuals (±standard deviation) within one square metre as assessed through light-trapping in Sg. ISME site.

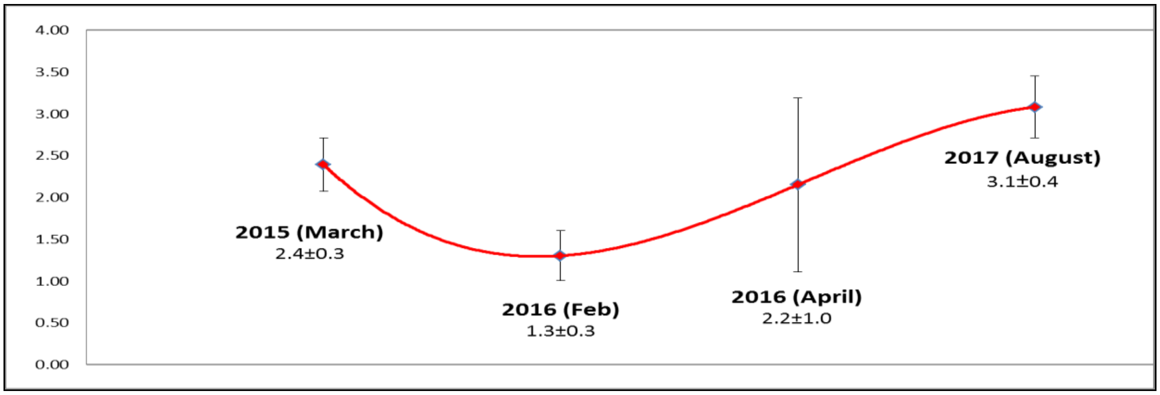

Figure 2c. Shannon Index (±standard deviation) within one square metre as assessed through light-trapping in Sg. ISME site.

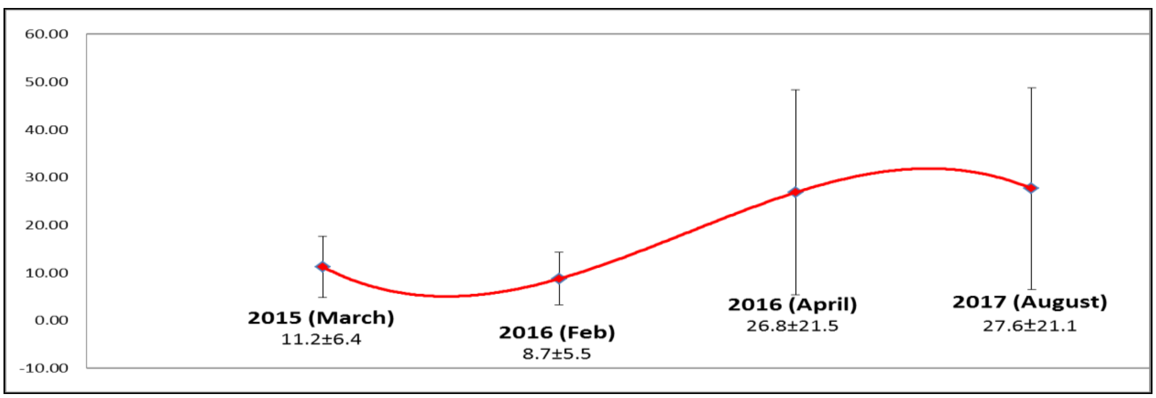

Figure 2d. Simpson Index (±standard deviation) within one square metre as assessed through light-trapping in Sg. ISME site.

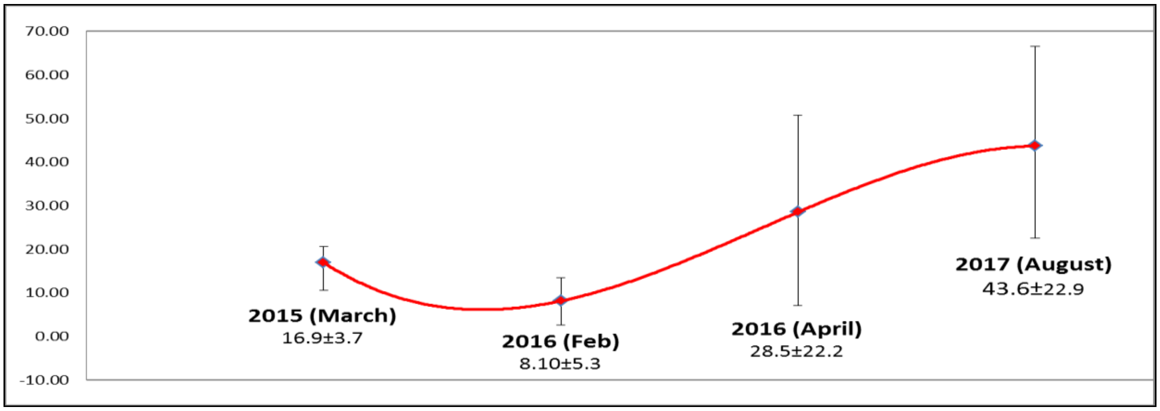

Figure 2e. Fisher Alpha Index (±standard deviation) within one square metre as assessed through light-trapping in Sg. ISME site.

The nocturnal insect species richness data of Sg. ISME in 2017 appears to be the lowest when compared with other forest reserves, as shown in Figures 3a. This is not surprising because Sg. ISME was a degraded area located within the mangrove vegetation which is low in plant diversity. It was only rehabilitated in 2012. Hence, relatively, plant diversity is much lower compared to mixed dipterocarp forest and montane forest, resulting in a poor insect fauna. Other mangrove forests, such as Tundon Bohangin within the Ramsar site and Sg. Kapur are also relatively low in species richness. In terms of insect abundance, more individuals are found in the inland mangrove Sg Kapur forest (Figure 3b), partly due to the proliferation of certain insect species in some parts of the transitional mangrove and lowland forest area. This trend, however, may not be significantly different because of the high standard deviation, as shown in Figure 3b. In nocturnal insect diversity (as reflected through Shannon Index), Sg. ISME and other mangrove sites are equally low compared to montane and lowland forests (Figure 3c).

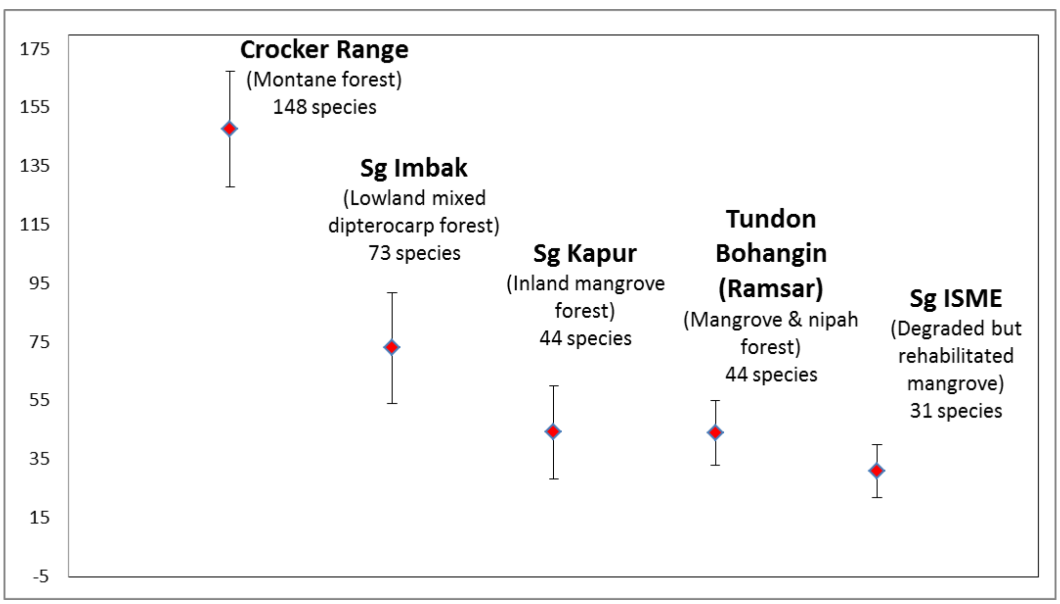

Figure 3a. Species number (±standard deviation) within one square metre as assessed through light-trapping in various forest reserves in Sabah.

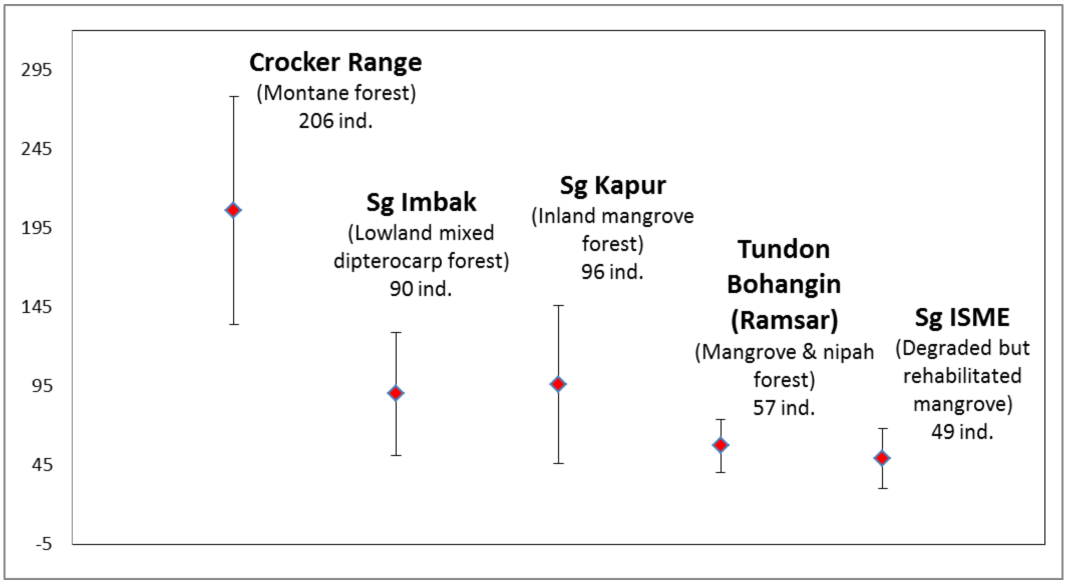

Figure 3b. Abundance (±standard deviation) within one square metre as assessed through light-trapping in various forest reserves in Sabah.

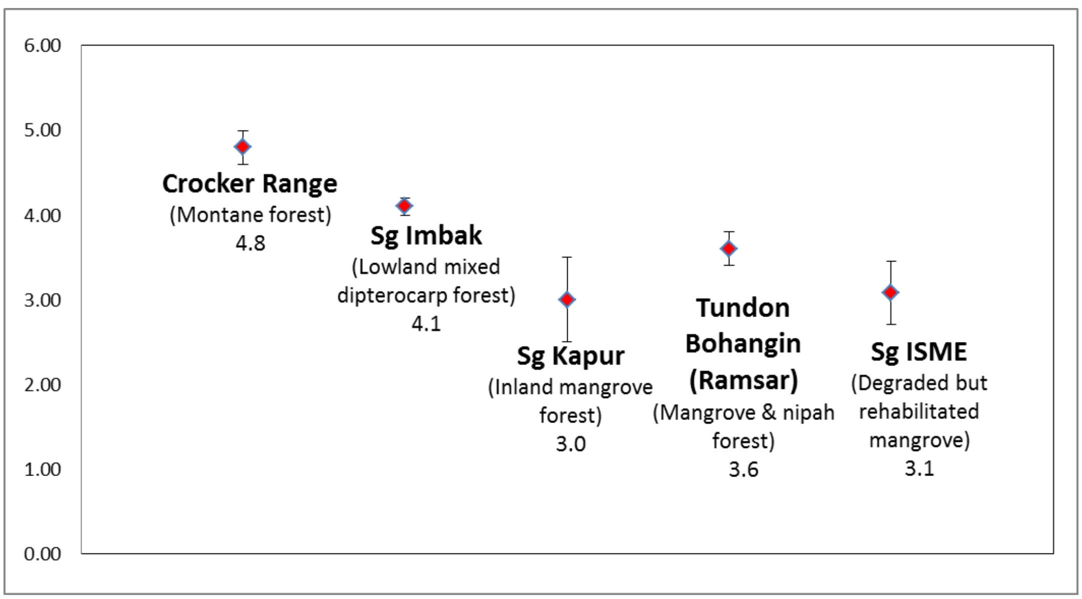

Figure 3c. Shannon Index (±standard deviation) within one square metre as assessed through light-trapping in various forest reserves in Sabah.

Insect fauna from Sg. ISME site

The insect data procured from the surveys in 2015 until 2017 serve as baseline information for this area. It can be used to evaluate the status of biodiversity in this mangrove rehabilitation area for the subsequent years. As pointed out by Nilus *et al.* (2014), through biodiversity documentation, key conservation target species could be highlighted for planning and formulation of conservation plans, and also for monitoring purposes in order to safeguard the integrity and well-being of the area. A small lycaenid butterfly, *Rapala pheretima pheretima*, is the only endemic subspecies recorded from Sg

ISME site. It is known as Copper Flash because of its dark brown colour. The species is common throughout Asia but this subspecies is only confined to Borneo.

Butterflies (Lepidoptera)

At least 20 butterfly species were recorded from Sg. ISME site, as listed in Appendix 1. Large and interesting species were the Mangrove Tree Nymph, *Idea leuconoe nigriana*, the Dark Glassy Tiger, *Parantica agleoides borneensis* and the Common Mormon, *Papilio polytes theseus*. The Mangrove Tree Nymph is a polka-dot butterfly, slow and graceful in flight, and it is a distinctive species of the mangrove environment. The Dark Glassy Tiger is another common species of the back mangrove habitats where the larvae feed on the foliage of the climber, *Tylophora flexuosa*. It is easily recognized through its brown with white lines and dots on its wings. The Common Mormon is a dark-coloured swallow-tailed butterfly with a series of white spots decreasing in size towards the apex on the upper forewing. The larvae have been reported feeding on the leaves of the Mangrove Lime, *Merope angulata*, which is known as 'Limau Buaya' in Malay. This butterfly is not only confined to mangrove swamps but also found in various other habitats. Other common nymphalid butterflies which were sighted during the survey include *Junonia atlites*, *Junonia orithya* and *Hypolimnas bolina*. Common lycaenid butterflies, *Hypolycaena erylus teatus* and *Arhopala pseudocentaurus*, were sighted feeding on the nectar of some flowering shrubs within the plot.

Moths (Lepidoptera)

A total of 29 moth species were recorded from Sg. ISME site, as listed in Appendix 1. Five hawk moth species were documented. Certain hawk moth species are pollinators (Tomlinson 1986) while some of the hawk moth caterpillars are defoliators (Nilus *et al*. 2010). A Lasiocampidae moth, *Trabala krishna*, and an Erebidae wasp-like moth, *Amata huebneri* were among the few interesting moths documented from Sg. ISME site. *T. krishna* is known to be commonly seen in mangrove habitats (Holloway 1998b). From the insect surveys in Sg. ISME, the day-flying moth, *A. huebneri*, was sighted visiting the Ketapang (*Terminalia catappa*) flowers. Many others are lesser-known micro-moths of the family Crambidae, such as *Omiodes diemenalis* and *Dichocrocis* nr *frenatalis*. The former has been recorded feeding on the woody climber of the genus *Derris* which is common in the mangroves (Robinson *et al*. 2001), while the latter genus is known to be a dominant insect in a mangrove forest in Guangxi (Jiang *et al*. 2000).

Beetles (Coleoptera)

At least 14 species of macro-beetles were recorded (Appendix 1). *Oryctes rhinoceros* was the largest beetle documented in this survey. This Rhinoceros Beetle is a pest in oil palm plantation and its presence was mainly due to the adjacent oil palm habitat. Other beetles sighted during the light-trapping include the Flower Beetle, *Glycyphana festiva* and Net-winged Beetle, *Lycostomus* sp. *G. festiva* was also found visiting the flowers of Ketapang during daytime. Other common beetles encountered in

Sg ISME site include the Leaf Chafers, *Anomala pallida* and *Adoretus compressus*. Both are defoliators of various plant species.

Dragonflies and damselflies (Odonata)

Dragonflies that were sighted during the surveys are all from the family Libellulidae, and a damselfly, *Argiocnemis rubescens*, from the family Coenagrionidae. Generally, mangroves harbour mainly eurytopic Odonata species which are common and able to tolerate a wide range of habitats (Orr 2003). Thus far, all those recorded from Sg. ISME site are common species. Both *Neurothemis ramburii* and *N. terminata* are common deep-red dragonflies in the lowlands. Similarly, *Orthetrum testaceum*, *O. glaucum* and *O. sabina* are also frequently encountered in similar habitats. *Rhyothemis phyllis* is a sun-loving, bee-like dragonfly that is often seen fluttering fairly high above the open areas. Dragonflies and damselflies are ecologically important in the mangroves as predators of mosquitoes and midges.

Other insects

Other insects recorded during the survey are listed in Appendix 1. They are from the order Hymenoptera, Hemiptera, Mantodea, Neuroptera, Orthoptera and Diptera. The Common Weaver Ant, *Oecophylla smaragdina*, is almost everywhere within the Sg. ISME plot. It is found nesting and foraging on the Ketapang tree. Clough (2013) reported that it is common to see large colonies of *O. smaragdina* throughout Asian mangroves. Although they usually farm scale insects for their honeydew, weaver ants also provide a useful service as predators of other more destructive insects. At night, a few species of the flying *Camponotus* ants were attracted to the light trap in Sg. ISME. Some sap-sucking bugs and a few cicada species of the order Hemiptera were recorded from Sg. ISME site. Praying mantises were also sighted but they were not able to be identified as they were still at the nymphal stage. *Chrysopa*, *Hybris* and *Myrmeleon* are among the neuropteran genera recorded from the site. As a group, they are commonly known as lacewings and antlions. However, not much is known about this insect order. Common orthopterans were documented, namely the Yellow Locust, *Valanga nigricornis*, the Bush Cricket, *Mecopoda* sp. and various other short-horned grasshoppers. They are often found in the open and grassy area of the Sg. ISME.

Insect diversity and the status of Sg. ISME site

In 2016, there was a drop in insect diversity which was also reflected in species richness and abundance in Sg. ISME site. This was primarily due to the drastic environmental degradation of the oil palm habitat located next to the Sg. ISME site. Many of the oil palm trees within the area died due to the sudden influx of the sea water with high salinity (Figure 4). It had created a clear and open environment. Thus, this situation had adversely affected the insect fauna in Sg. ISME. The unexpectedly hot and dry weather in 2015 in Borneo had also worsened the situation (Chen *et al*. 2016).

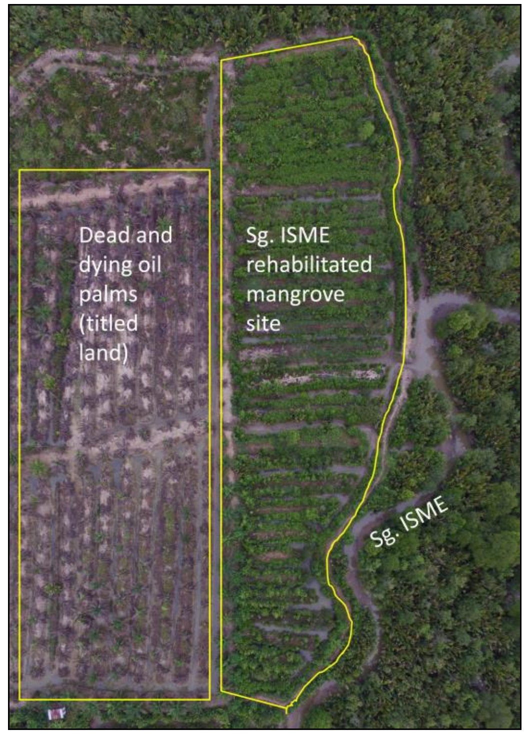

Figure 4. A drone photo taken in mid November 2015, showing the degraded oil palm habitat next to the Sg. ISME site (Photo: Shin Watanabe).

Overall, there is an increase of insect diversity in Sg. ISME study site but it is still relatively low when compared to other ecosystems. Field (1995) has mentioned that insects are not particularly diverse in mangrove and nipah vegetation compared to lowland mixed dipterocarp forest. The findings from this survey also concur with the results from the insect survey in other mangrove forests, e.g. Tundon Bohangin and Sg. Kapur, which showed low species richness as well as abundance. Grampurohit & Karkhanis (2013) pointed out that insect fauna is poorly known in the mangroves compared to larger animals and plants. Study on insect diversity can help in determining its potential productivity and in better management of mangroves. Such a study can also highlight the need for biodiversity conservation to preserve the natural balance of the mangrove ecosystem.

Despite its low diversity, mangrove is home to certain interesting insect species, such as the Mangrove Tree Nymph butterfly and fireflies, which have the potentials in increasing economical productivity for the local communities. Some are ecologically important to the mangrove trees as pollinators as well as pests, especially some of the moth larvae as reported by Chung *et al*. (2010), and Chung & Tangah (2013). Towards the inner part of the mangroves, termites were seen causing damage to some of the trees. Mangroves have an unenviable reputation for breeding and harbouring large numbers of biting insects, such as mosquitoes and midges (Field 1995). Hence, mangrove forests are often considered as harsh environment by humans.

As mangrove forest is transitional between land and sea, insects that are found in this ecosystem are those that can adapt in this transitional coastal environment. Besides the low plant diversity, insects living within Sg. ISME should be able to adapt to drastic changes in microclimate, such as strong wind and waves, high salinity, as well as intense sunlight. Hence, this could also be one of the reasons for the lower insect species richness in such environment when compared to others. Nevertheless, insects are still important in the food chain and energy flow in the mangrove ecosystem, especially in this succession period. For example, mosquitoes and midges are source of food for the carnivorous dragonflies which in turn may be eaten by insectivorous birds. It is hoped that insect diversity within Sg. ISME site will continue to improve over the years and this would contribute to a better and stable mangrove ecosystem.

CONCLUSION

From this study, it shows an increase and improvement for the number of species recorded and insect diversity within Sg. ISME site compared to previous surveys. The low insect diversity compared to other forest reserves was due to low plant diversity and harsh environment which only certain insect species could adapt in the habitat. Rehabilitation in Sg. ISME started almost five years ago and it is hoped that insect diversity will continue to increase in the following years when the ecosystem is more stable through the ecological succession from the trees planted.

Insect data recorded during the survey provide salient information to enhance biodiversity conservation of this area which is of scientific importance for the collaboration between ISME and SFD, as well as TBRC. Insects are ecologically significant in the mangrove ecosystem as pollinators, defoliators, borers, decomposers as well as source of food for other animals, and will undoubtedly contribute to the success of mangrove rehabilitation. Research within Sg. ISME, e.g. insect diversity, will further strengthen the collaboration between ISME and SFD in terms of information sharing for better management of mangrove rehabilitation in Sabah.

This research also serves as a guide to other research and development plan for mangrove rehabilitation. Silvicultural practices on the mangrove trees should be maintained for developing well-growth trees. In addition, it also helps to form forest areas that provide basic services of nature in critical situation (HCV4) as the mangroves function to protect the coastline in which they filter out sediments.

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Appendix 1. Insects recorded from Sg. ISME mangrove rehabilitation site, Sabah.

No.	Species	Author	Family	Photo code	Photo number
	Coleoptera (Beetles)				
1	*Ceresium* sp.		Cerambycidae	DSCN	2087
2	*Tetraommatus* sp.		Cerambycidae	ACD	8471
3	*Cicindela* sp.		Cicindelidae	DSCN	2087, IMG7843
4	*Pheropsophus* sp.		Cicindelidae	IMG	7967
5	Unidentified		Dryopidae	ISM	4111, 4117
6	*Aegus* sp.		Lucanidae	DSCN	2071
7	*Lycostomus* sp.		Lycidae	IMG	8079
8	*Adoretus compressus*	Weber	Scarabaeidae	DSCN	2078
9	*Anomala pallida*	Fabricius	Scarabaeidae	ISM	4114, IMG7980
10	*Anomala* sp.		Scarabaeidae	DSCN	2054
11	*Glycyphana festiva*	Fabricius	Scarabaeidae	IMG	8076
12	*Maladera* sp.		Scarabaeidae	IMG	7861
13	*Oryctes rhinoceros*	Linnaeus	Scarabaeidae	ISM	4134, IMG8005
14	Unidentified		Staphylinidae	ISM	4108
	Diptera (Flies)				
1	*Sarcophaga* sp.		Sarcophagidae	IMG	7793
2	Unidentified		Syrphidae	DSCN	5540
	Hemiptera (Bugs)				
1	*Platylomia* sp.		Cicadidae	ISM	4124, 4123, 4112
2	*Purana* sp. 1		Cicadidae	ACD	8499
3	*Purana* sp. 2		Cicadidae	IMG	8060
4	*Peltoxys* sp.		Cydnidae	ISM	4109
5	*Pyrrhocoris* nr *carduelis*	Stal	Pyrrhocoridae	ISM	4101
6	Hemiptera nymph			ISM	4065, IMG7778
	Hymenoptera (Ants, Bees & Wasps)				
1	*Camponotus* sp. 1		Formicidae	ISM	4118
2	*Camponotus* sp. 2		Formicidae	ISM	4125
3	*Camponotus* sp. 3		Formicidae	IMG	7872
4	*Dorylus* sp.		Formicidae	DSCN	2085
5	*Oecophylla smaragdina*	Fabricius	Formicidae	ISM	4093, 4053, 4094
6	*Provespa anomala*	Saussure	Vespidae	ACD	8481, IMG7827
7	*Vespa* sp.		Vespidae		Spotted
8	*Xylocopa* sp.		Xylocopidae	ISM	4053

	Lepidoptera (Butterflies)				
1	*Taractrocera ardonia sumatrensis*	Evans	Hesperiidae	IMG	8037
2	*Anthene emolus*	Fruhstorfer	Lycaenidae	ISM	4090
3	*Arhopala pseudocentaurus*	C & R Felder	Lycaenidae	ISM	4069, 4063, 4064
4	*Hypolycaena erylus teatus*	Fruhstorfer	Lycaenidae	IMG	7754, ISM4092
5	*Rapala pheretima pheretima*	Hewitson	Lycaenidae	ISM	4074
6	*Rapala* sp.		Lycaenidae	DSCN	2096
7	*Euploea midamus*	Butler	Nymphalidae	DSCN	2098
8	*Hypolimnas bolina philippensis*	Butler	Nymphalidae	DSCN	2050, IMG7723
9	*Idea leuconoe nigriana*	Grose-Smith	Nymphalidae	DSCN	2041, 2040
10	*Ideopsis vulgaris interposita*	Fruhstorfer	Nymphalidae	ISM	4068
11	*Junonia atlites atlites*	Linneaus	Nymphalidae	IMG	7913
12	*Junonia orithya metion*	Fruhstorfer	Nymphalidae	DSCN	2097
13	*Neptis hylas sopatra*	Fruhstorfer	Nymphalidae	DSCN	2090, IMG7916
14	*Pantoporia paraka paraka*	Butler	Nymphalidae	IMG	7930
15	*Parantica agleoides borneensis*	Staudinger	Nymphalidae	ISM	4073, IMG7761
16	*Polypura hebe ganymedes*	Staudinger	Nymphalidae	IMG	7910
17	*Graphium aristeus hermocrates*	C & R Felder	Papilionidae		Spotted
18	*Papilio polytes theseus*	Cramer	Papilionidae	IMG	7926
19	*Eurema hecabe hecabe*	Linnaeus	Pieridae	DSCN	2051
20	*Eurema sari sodalis*	Moore	Pieridae	ISM	4070, 4071
	Lepidoptera (Moths)				
1	*?Cnaphalocrosis* sp.		Crambidae	IMG	7976
2	*?Maruca* sp.		Crambidae	IMG	8012
3	*Dichocrocis* nr *frenatalis*		Crambidae	ISM	4108, IMG7846
4	*Maruca* nr *testulalis*	Geyer	Crambidae	IMG	8072
5	*Omiodes diemenalis*	Guenée	Crambidae	IMG	8006
6	*Syllepte* sp.		Crambidae	DSCN	2053
7	Unidentified		Crambidae	DSCN	2057
8	Unidentified		Crambidae	DSCN	2063
9	*Amata huebneri*	Boisduval	Erebidae	DSCN	5529
10	*Asota* nr *heliconia*	Linneaus	Erebidae	IMG	8070
11	*Calliteara* sp.		Erebidae	IMG	8056
12	*Cyana* nr *selangorica*	Hampson	Erebidae	ISM	4127, IMG7857
13	*Cyme* nr *reticulata*		Erebidae	IMG	7834
14	*Hypochrosis binexata*	Walker	Geometridae	ISM	4116
15	*Zamarada* sp.		Geometridae	IMG	8011
16	*Euthrix laeta*	Walker	Lasiocampidae	ACD	8487, IMG7991
17	*Trabala krishna*	Roepke	Lasiocampidae	ISM	4122
18	*Setora cupreistriga*	Walker	Limacodidae	ACD	8482
19	*Thosea vetusta*	Walker	Limacodidae	ACD	8472

20	*Squamura disciphaga*	Swinhoe	Metarbelidae	ACD	8493
21	Unidentified		Noctuidae	DSCN	2058
22	Unidentified		Noctuidae	DSCN	2065
23	Unidentified		Noctuidae	ISM	4115
24	*Acosmeryx shervillii*	Boisduval	Sphingidae	ACD	8465
25	*Hippotion* sp.		Sphingidae	IMG	8069
26	*Theretra boisduvalii*	Bugnion	Sphingidae	ACD	8477
27	*Theretra latreillei*	Macleay	Sphingidae	IMG	7873
28	*Theretra suffusa*	Walker	Sphingidae	ACD	8484, IMG7988
	Mantodea (Praying Mantises)				
1	Unidentified		Mantidae	DSCN	2077
2	Unidentified nymph		Mantidae	ISM	4081
	Neuroptera (Lacewings & Ant-lions)				
1	*Chrysopa* sp. 1		Chrysopidae	DSCN	2093
2	*Chrysopa* sp. 2		Chrysopidae	IMG	8001
3	*Hybris* sp.		Myrmelontidae	IMG	7825
4	*Myrmeleon* sp. 1		Myrmelontidae	ISM	4113
5	*Myrmeleon* sp. 2		Myrmelontidae	IMG	7860
	Odonata (Dragonflies & Damselflies)				
1	*Argiocnemis rubescens*	Selys	Coenagrionidae	IMG	7809
2	*Aethriamanta gracilis*	Brauer	Libellulidae	IMG	8049
3	*Diplacodes trivialis*	Rambur	Libellulidae	IMG	8022
4	*Neurothemis ramburii*	Brauer	Libellulidae	ABC	7690
5	*Neurothemis terminata*	Ris	Libellulidae	ISM	4085, IMG7917
6	*Orthetrum glaucum*	Brauer	Libellulidae	DSCN	2048
7	*Orthetrum sabina*	Drury	Libellulidae	IMG	7805
8	*Orthetrum testaceum*	Burmeister	Libellulidae	DSCN	2091
9	*Rhyothemis phyllis*	Sulzer	Libellulidae	IMG	7732
	Orthoptera (Grasshoppers & Bush Crickets)				
1	*Stenocatantops* sp.		Acrididae	IMG	7936
2	*Trilophidia* sp.		Acrididae	ISM	4059
3	*Valanga nigricornis*	Burmeister	Acrididae	ISM	4097
4	*Gryllotalpa orientalis*	Burmeister	Gryllotalpidae	IMG	7990
5	*Mecopoda* sp. 1		Tettigoniidae	ISM	4107
6	*Mecopoda* sp. 2		Tettigoniidae	IMG	7963, 7768
7	Unidentified nymph		Tettigoniidae	ISM	4102

A brief note on *Ternstroemia* (Pentaphylacaceae) of Tama Abu P.F., Ulu Baram, Sarawak, Malaysia

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Abstract. A specific collection of *Ternstroemia* was made during a scientific expedition under the Heart of Borneo (HoB) initiative in Tama Abu Permanent Forest (P.F.), Ulu Baram, Sarawak from 15th to 26th of August 2017. The study was aimed to collect and identify all species of *Ternstroemia* found within the area. There were four species collected in Tama Abu P.F., i.e., *T. aneura* Miq., *T. bancana* Miq., *T. lowii* Stapf. and *T. magnifica* Stapf. ex Ridl.. These four species are common in the highlands and *kerangas* habitats of Borneo. To date, there are 17 species of *Ternstroemia* that are recognised in Borneo (including possibly eight species new to science) whereby 16 species are recorded from Sarawak. The findings from this expedition will be included in the ongoing taxonomic revision of *Ternstroemia* in Borneo and also the Tree Flora of Sabah and Sarawak documentation.

Keywords: Borneo, scientific expedition, taxonomic revision

INTRODUCTION

Ternstroemia (previously included in the Theaceae family) is a pantropical genus of about 100 species, consisting of trees, shrubs and epiphytes. This genus is commonly found in the lower to upper montane forests, occasionally in lowland mixed dipterocarp and *kerangas* forests, particularly along riverbanks and forest on ultramafic soil, on altitude up to 4000 m.

A comprehensive taxonomic revision of the genus in Borneo is currently being undertaken by the first author. Thus far, there are 17 recognised species of *Ternstroemia* in Borneo. Previous researchers who studied this genus in Borneo, i.e., Cockburn (1980), Argent *et al*. (1997), Coode e*t al*. (1996) and Anderson (1980), had only listed the species based on respective territories within the island without any detail descriptions of each species. For example, Anderson (1980) had listed nine species of *Ternstroemia* from Sarawak, namely *T. aneura* Miq., *T. bancana* Miq., *T. citrina* Ridl., *T. denticulata* (Pierre) Ridl., *T. hosei* Ridl., *T. lowii* Stapf., *T. macrocalyx* Airy Shaw, *T. magnifica* Stapf. ex Ridl. and *T. penangiana* Choisy and one undetermined species. Unfortunately, no key to the species was provided.

In Sarawak, this genus is locally known as Medang Pajal, particulary by the Iban community (Anderson 1980) as seen in specimen labels and also from personal communication with botanists and collectors during several fieldwork conducted in Sarawak. The term Medang Pajal is also referring to certain species based on the leaf sizes (either small or big) e.g., *T. hosei* is specifically known as Medang Pajal Daun Kecil due to its small leaves. Similarly, species with big-sized leaves, such as *T. magnifica*, is known as Medang Pajal Daun Besar (Anderson 1980).

There are no specific uses of *Ternstroemia* in Borneo, but some information from the specimen labels, especially those from Ranau and Telupid districts in Sabah, noted that the wood of *T. bancana* is normally used by local people for house construction. In Peninsular Malaysia, the wood of this species was listed as a timber species by Ridley (1922). In terms of conservation, *T. bancana* has a good potential to be used for restoration of degraded areas as 90% of its seeds could be germinated within a month period (Sosef *et al*. 1998).

Under the Heart of Borneo (HoB) Sarawak initiative, a scientific expedition at Tama Abu P.F. was conducted to study the fauna and flora diversity, the aquatic habitat, the sociology and anthropology of the local communities and tourism potential of the area with a view in contributing to the well-being of the local communities and enhancing conservation. A specific study on *Ternstroemia* species (Pentaphylacaceae) was conducted within the area with the objective to collect and identify all species of *Ternstroemia* found within the area.

MATERIAL AND METHODS

Study Site

Tama Abu Range is a mountain range located in Sarawak and is nearby to Long Labid, Raan Ngela and Long Aar. The expedition site is located at about N 03º 18’ 37.1”, E 115º 28’ 48.7” in the south eastern of Pulong Tau National Park (Figure 1). The site is about 130 km from Miri Town and is only accessible by four-wheel drive car (about 11-hour drive). Basically, the area is covered by patches of virgin forests and, was logged-over about 20 years ago. The area is surrounded by hilly forests with several peaks reaching to 1000 m a.s.l. The closest settlement of the Penan people is Kg. Long Banga, about an hour drive from the expedition site. The vegetation of Tama Abu P.F. consists of the lowland to upland hill dipterocarp and *kerangas* forests.

Sampling of plants

Collections of *Ternstroemia* were carried out along Trail No. 1 to Trail No.11, which were established along Sg. Balleh. The vegetation types along these trails are mostly lowland hill dipterocarp, upland dipterocarp, *kerangas* forests (peak of Trail No. 4), and the elevation ranges from 250 m to 1018 m a.s.l.

In the field, the habit, and the colour of leaves and other parts of plants were recorded for each collection. About 4–6 duplicates of voucher specimens (consisting of leafy twigs without fruits or flowers) were gathered. Digital images of habit and close-up views of other parts of the plants were taken. Prior to identification, the specimens were oven-dried at a temperature range of 45–50°C for several days at Sarawak Herbarium (SAR). Further identification was done at Sandakan Herbarium (SAN) by cross-checking with herbarium specimens and the literature materials.

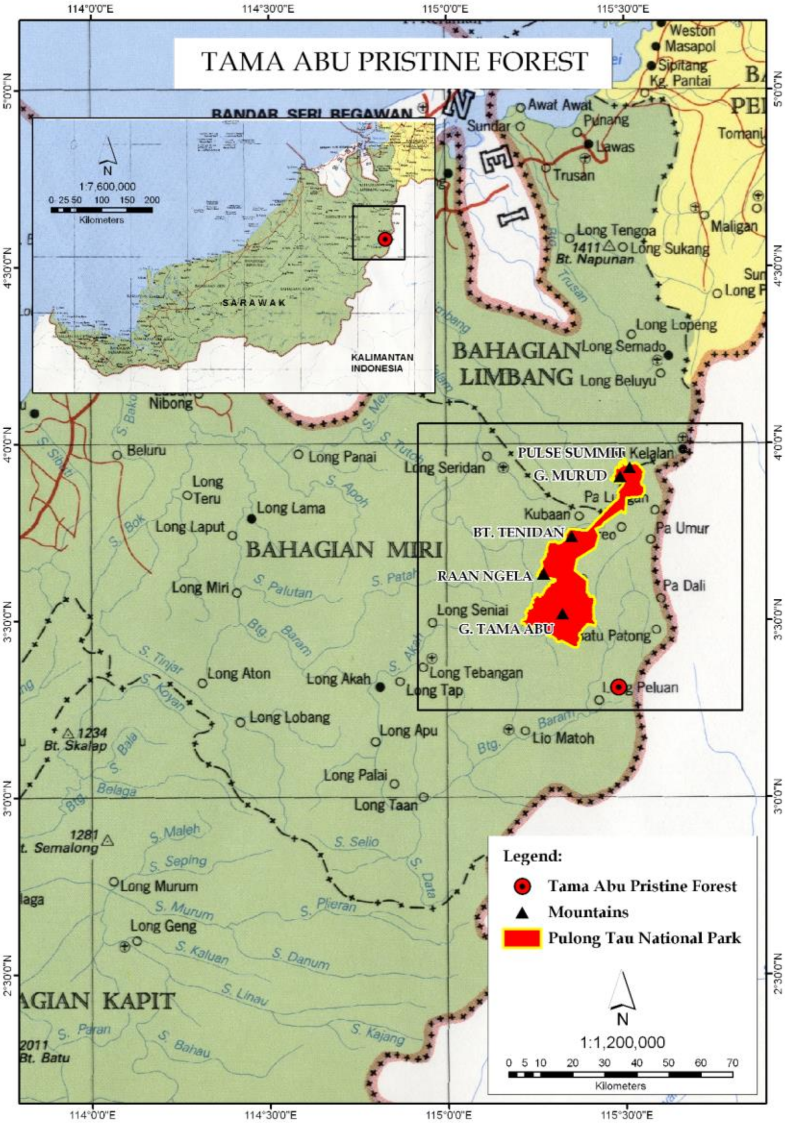

Figure 1. The location of Tama Abu P.F. in Sarawak, Malaysia (source: GIS Unit, Forest Research Centre, Sabah Forestry Department).

RESULTS AND DISCUSSION

A total of six specimens, representing four species of *Ternstroemia*, i.e., *T. aneura*, *T. bancana*, *T. lowii* and *T. magnifica* were collected in Tama Abu P.F., along Trails 2, 4, 6 and 7 (Table 1). *Ternstroemia lowii* which is found in *kerangas* forest is an endemic species to Borneo. The other three species are common and widespread in the highlands of Borneo. A short note on each species is included in this paper. These findings, however, are far from complete due to lack of collection because of the unfavourable weather during the expedition. The flowering and fruiting seasons were over as a few seedlings were seen on the forest floor.

Thus, all of the specimens collected were sterile. However, the finding of the four species of *Ternstroemia* is useful for added information, especially on the locality and distribution of this genus in Sarawak. The pristine environment coupled with fresh clear river of Sg. Balleh and high humidity throughout the day, provided an ideal condition for the Asian species of *Ternstroemia* to grow well (Ridley (1922), Kobuski (1963), Keng (1978), Coode *et al*. (1996), Beaman & Anderson (2004).

Table 1. Collection details and the coordinates of *Ternstroemia* specimens at Tama Abu P.F.

Species Collected	Collection No.	Trail No.	Geographical Position	Elevation (m)
T. aneura Miq	SAN 158681	Trail No. 2	N 03° 19’ 06.7” E 115° 28’ 42.4”	955
	SAN 158686	Trail No. 4	N 03° 18’ 49.1” E115°28’32.1”	920
	SAN 158688	Trail No. 6	N 03° 18’ 31.1” E115°28’28.4”	838
T. bancana Miq.	SAN 158694	Trail No. 4	N 03° 18’ 30.0” E115°28’27.3”	893
T. magnifica Stapf. ex Ridl.	SAN 158689	Trail No. 6	N 03° 18’ 32.2” E115°28’22.9”	908
T. lowii Stapf.	SAN 158687	Trail No. 7	N 03° 18’ 57.8” E115°28’30.5”	1018

Short notes on *Ternstroemia* species from Tama Abu P.F.

***Ternstroemia aneura* Miq.** (Figure 2)

Small tree, *c.* 5 m tall, 4 cm in diameter; buttresses absent. **Bark** smooth to flaky or cracking, greyish to reddish brown; inner bark dark red, fibrous. **Sapwood** yellowish. **Twigs** terete, drying greyish brown, smooth, glabrous. **Leaves** dark green above, paler beneath, thin-coriaceous, smooth and glabrous on both surfaces; blade ovate, 2.5–8 × 2.5–4.5 cm, base cuneate, margin slightly involute or wavy, apex rounded or acute; midrib slightly channelled above, raised below; lateral veins indistinct on both surfaces, 3–5 pairs, slightly joining near the margin; intercostal venation slightly distinct above, indistinct below; petiole glabrous, slender, 0.3–2 cm long.

Distribution: Sumatra, Peninsular Malaysia, Borneo, the Philippines, Papua New Guinea and Java. In Sarawak, known from Bario, Kapit, Kuching, Lawas, Lundu, Marudi, Miri, and Serian districts.

Notes: This species is common in Tama Abu P.F. and also it is the most common species in Borneo. A few individuals that were seen along the trail were small trees, about 5 m tall and less than 5 cm diameter. It is easy to recognise this species in the field as it has small leaves (less than 8 cm long) with indistinct nerves on both surfaces. The twig, petiole and pedicel are greyish-brown and rounded. The indistinct nerves of its leaves, and rounded twig, petiole and pedicel can differentiate this species from the two closely related species that also have small leaves, i.e., *T. bancana* and *T. lowii*.

Figure 2. The flowering branch of *T. aneura*.

***Ternstroemia bancana* Miq.** (Figure 3)

Medium-sized tree, *c.* 10 m tall, 11 cm in diameter; buttresses absent. **Bark** smooth to flaky or cracking, whitish or greyish; inner bark orangey, fibrous. **Sapwood** yellowish. **Twigs** sub angular, drying whitish or greyish, smooth and spotted with minute black dots, glabrous. **Leaves** coriaceous, smooth and glabrous on both surfaces, spotted with minute black dots or slightly glaucous below; blade oblanceolate-obovate, 6–10 × 3.4–7.2 cm, base cuneate, margin smooth, apex acute, obtuse, retuse; midrib slightly channelled above, raised below; lateral veins indistinct on both surfaces, 5–6 pairs, slightly joining near the margin; intercostal venation indistinct on both surfaces; petiole drying dark brown, glabrous, stout, 0.6–2 cm long.

Distribution: Sumatra, Peninsular Malaysia, Singapore and Borneo. In Sarawak, it is common and widespread in Kapit, Kuching, Marudi and Miri districts.

Notes: Only one individual of this species was found during the expedition. This species is easy to recognise by its whitish and angular twig, petiole and pedicels. The nerve is distinct, especially on the upper surface of the leaves.

Figure 3. The fruiting branch of *T. bancana*.

***Ternstroemia magnifica* Stapf. ex Ridl.** (Figure 4)

Medium-sized tree, *c.* 15 m tall, *c.* 13 cm diameter; buttresses absent. **Bark** smooth to lenticellate, cracking, reddish pink or brown; inner bark yellowish, granular or mottled. **Sapwood** pale yellow to brownish pink, fibrous**.** **Twigs** terete, drying greyish brown, fissured, glabrous. **Leaves** thick coriaceous, glabrous and smooth on both surfaces, slightly glaucous below; blade obovate, 10.5–17 × 7–10 cm, base cuneate or slightly decurrent, margin entire, apex obtuse or abruptly acuminate, acumen *c.* 0.2 cm long; midrib slightly to deeply channelled above, raised below; lateral veins indistinct to distinct on both surfaces, 9–14 pairs, slightly joining near the margin; intercostal venation distinct on both surfaces; petiole drying dark brown to blackish, glabrous, stout, 2–4 cm long.

Distribution: Peninsular Malaysia, Borneo, the Philippines and New Guinea. In Sarawak, recorded from Bintulu, Kuching, Lawas, Lundu and Miri districts.

Notes: This species is common on the highlands of Borneo. It is easy to recognise from the other three species of *Ternstroemia* in Tama Abu P.F. due to its tree size, large leaves, and stout and long petiole. In addition, the young shoots of the leaves are normally reddish in colour. This species could reach up to 40 m tall with 40 cm dbh, however, the tallest individual in the study site is only 15 m tall.

Figure 4. The fruiting branch of *T. magnifica.*

***Ternstroemia lowii* Stapf.** (Figure 5)

Treelet, *c.* 5 m tall, *c.* 5 cm diameter; buttresses absent. **Bark** smooth, whitish; inner bark reddish brown, fibrous. **Sapwood** pale yellow**.** **Twigs** terete or slightly subangular, glabrous. **Leaves** thick coriaceous, shining, rugulose above, smooth below, glabrous on both surfaces; blade elliptic, obovate 3.5–8 × 1.5–3.5 cm, base oblique; margin slightly involute, apex rounded, acute or short acuminate, acumen *c*. 0.1 cm long; midrib sunken above, raised below; lateral veins indistinct on both surfaces, 4–6 pairs, slightly joining near the margin; intercostal venation indistinct on both surfaces; petiole drying brown to black, glabrous, stout, 0.5–2 cm long.

Distribution: Endemic to Borneo (Sabah, Sarawak, Brunei and Kalimantan). In Sarawak, it is recorded from Baram, Bario, Bintulu, Kapit, Kuching, Lawas, Limbang, Marudi, Miri and Sri Aman districts.

Notes: This species is commonly found in the montane forests of Borneo. The shinning, waxy and thick leaves are the distinguishing characters of this species. The twig, petiole and pedicel of this species are rounded. Only one individual was found in the *kerangas* habitat of Tama Abu P.F.

Figure 5. The fruiting branch of *T. lowii.*

CONCLUSION

Even though only four species of *Ternstroemia* were recorded in Tama Abu P.F., there were a few seedlings of *T. aneura* observed along the trails especially on the hilly parts with elevation above 800 m a.s.l. The *kerangas* forest in high elevation, particularly the peak of Trail No. 7, is an important habitat for the endemic species, *T. lowii*, as only one individual tree of this species was found during the expedition. It is recommended to carry out further collection of *Ternstroemia* during flowering or fruiting seasons, especially in areas that were not covered during the expedition. In addition, this is also the first record of *Ternstroemia* collection from Tama Abu P.F. as fieldwork has never been conducted in the area before.

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Defoliation symptoms on trees planted at a restoration site in Sabah, Malaysia

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Abstract. A study on defoliation of selected tree species was conducted at a forest restoration site located at Species Demo Plot in Luasong, Tawau Sabah. The study site is part of the INIKEA Forest Rehabilitation Project managed by Yayasan Sabah. The objective of this study was to determine the type and variation of defoliation symptoms observed on the foliage of eight to ten years old trees of *Dipterocarpus conformis* (KBK), *Diospyros* sp. (KMLM), *Dryobalanops lanceolata* (KPJ), *Pentace laxiflora* (TDH), *Pentace adenophora* (TDB) and *Hopea ferruginea* (SMKU) that were planted by line planting method. Sampling was conducted in July 2017 for a period of one week. Four replicates for each tree species was sampled. Defoliation symptoms were assessed on the crown of the trees. The mean defoliation symptom occurrence was calculated to represent each tree species. The mean defoliation symptoms among the six tree species were tested by using the Chi-square statistical analysis. Defoliation symptom occurrence across the six species of trees was categorized as herbivory, egg cases, leaf miners, leaf rollers, and galls. The highest percentage of defoliation symptom was herbivory (44.71%), followed by both egg cases and leaf miners (24.71% respectively), and only 1.18% of galls, which was the lowest. The highest mean defoliation symptom occurrence was recorded on *D. lanceolata*, with a mean of 4.75 occurence, while the lowest mean defoliation symptom occurrence of 3.00 was recorded on both *Diospyros* sp. and *H. ferruginea.* Results of the Chi-square analysis indicated no significant difference ($p>0.05$) in the mean occurrence of defoliation symptoms across the six species of trees.

Keywords: leaf defoliation, defoliation symptoms, insects, pests, restoration

INTRODUCTION

Insects represent a dominant component of biodiversity in most of the terrestrial ecosystems (Weisser & Siemann 2008). They play various roles and contribute various services to the ecosystem, such as decomposers and pollinators, which are beneficial to the trees and forest ecosystem. However, insects that feed on various parts of living trees can cause damages which bring a negative impact on tree growth and survival. Insects that cause damages which lead towards economic losses are considered as pests (Nair 2007). The situation becomes worst when uncontrolled population of insects in the forest causes insect outbreak that can damage the host plants. In most forests, approximately two-thirds of the insect pest species are from the orders Coleoptera and Lepidoptera (Howe & Jander 2008).

Generally, various species of insects are associated with a species of tree which cause various types of insect attack or nests in different parts of the tree or plant itself. However, not all insects that attack or live in a tree becomes a serious pest until its population increases and causes serious damage to the plant. On the contrary, plants have their own defence mechanism against any potential pests or diseases through a combination of direct defence traits that involves physical and chemical barriers which interferes with insect growth, reproduction and development; and indirect defence approaches through the release of volatile compounds that can attract natural enemies which can suppress the pests (Belete 2018). In addition, the chemical and nutritional properties in trees and plants make only certain plants being favoured by certain groups of insects, which creates the host-specificity pattern (Ernest 1989, Nair 2007).

Insects that are specialised on feeding or consuming certain parts of a tree or plant have specialised mouthparts that are well-designed for different feeding habits such as leaf feeders, sap feeders, stem feeders and miners (Howe & Jander 2008). Despite of the different feeding behaviour, insects are the key players of the forest ecosystem as they interact with other living organisms in numerous ways. Insects play a vital role in the ecosystem processes at two trophic levels; as primary consumers and also as decomposers (Nair 2007). Little do we know that these interactions may influence primary production, succession and evolution of plant communities in the forest ecosystems.

Defoliation based on entomological context is normally caused by herbivorous insects that consume on leaf, which include leaf-chewers, leaf skeletonizers, leaf miners, leaf rollers, shoot-borers and sap feeders (Chey 1995). This makes the tree defoliating insects responsible in altering the plant architecture as a result of its feeding patterns either for food or shelter building purposes (Ginocchio & Montenegro 1994). Among the common tree defoliation symptoms that can be found on the foliage of trees include domicile, leaf rollers, galls, miners, borers and skeletonizers (Nair 2007, Ribeiro & Basset 2007). The type of damages varies considerably according to tree and insect species, feeding intensity and time of the year when the feeding occurs. In general, the effect of defoliation can be negligible. However, when an outbreak happens, it may cause significant damage to an individual tree.

Herbivory, for example, is one of the defoliation symptoms caused by herbivorous insects that can lead towards a significant impact on plants and trees, as it involves the partial or whole consumption of leaves which affects the photosynthesis and other physiological processes that could be detrimental to an individual plant. The general impact of leaf herbivory in a mixed-species forest is lower compared to a mono-species forests or plantations (Jactel & Brockerhoff 2007). Therefore, in the case of forest restoration sites, the more diverse the species composition of trees in the site would showcase lower herbivory activities. In addition to that, plant vigour also oversees the dynamics of a forest. Insects are more interested in consuming fast-growing plants, as these plants produce higher nutrients that make them more preferable to herbivorous insects, thus causing severe herbivory activities on the target plants (Price 1991).

MATERIALS AND METHODS

Study site

This study was conducted at the Species Demo Plot which is located in Luasong, Tawau, Sabah (4°36' N, 117°14' E), as shown in Figure 1. The total area of the Species Demo Plot is two hectares, with a total of 34 species of trees comprising Dipterocarps, non-Dipterocarps and fruit trees species planted in the site (Figure 3). Trees were planted in 2008 by line planting method at a distance of two meters between each tree. The restoration project was initiated in 1988, funded by the Innoprise-IKEA (INIKEA), a collaborative project between the Sow-A-Seed Foundation of IKEA, Sweden and Innoprise Corporation Sdn. Bhd. This project was established in the Yayasan Sabah Concession Area with the main aim to enhance biodiversity and assist recovery of severely degraded forest caused by wild forest fire in 1982 and 1983. Prior to the wild forest fire incident, the forest in the INIKEA site was degraded due to intense unsustainable logging practices between 1970 and 1980.

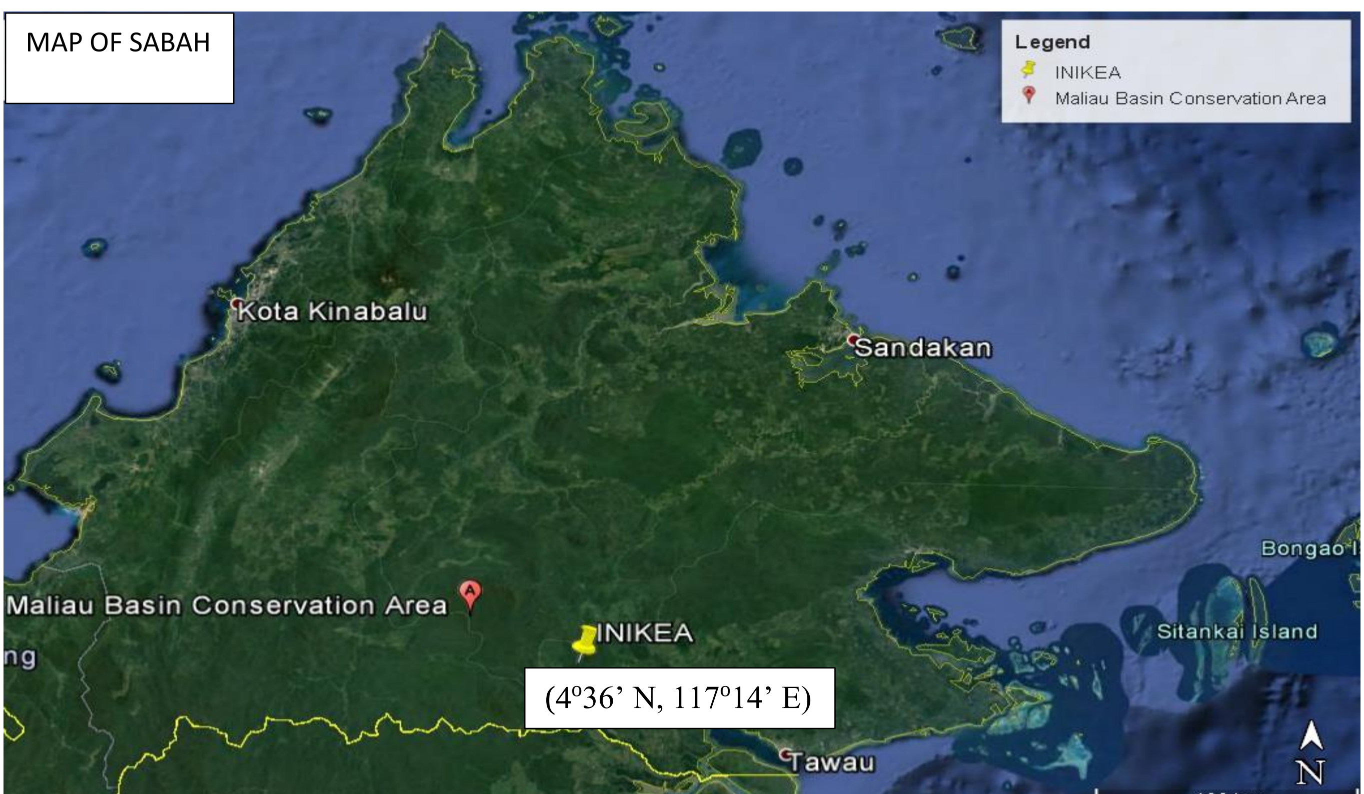

Figure 1. Location of INIKEA Project Site in Sabah, Malaysia. (Source: Google Maps, 2018)

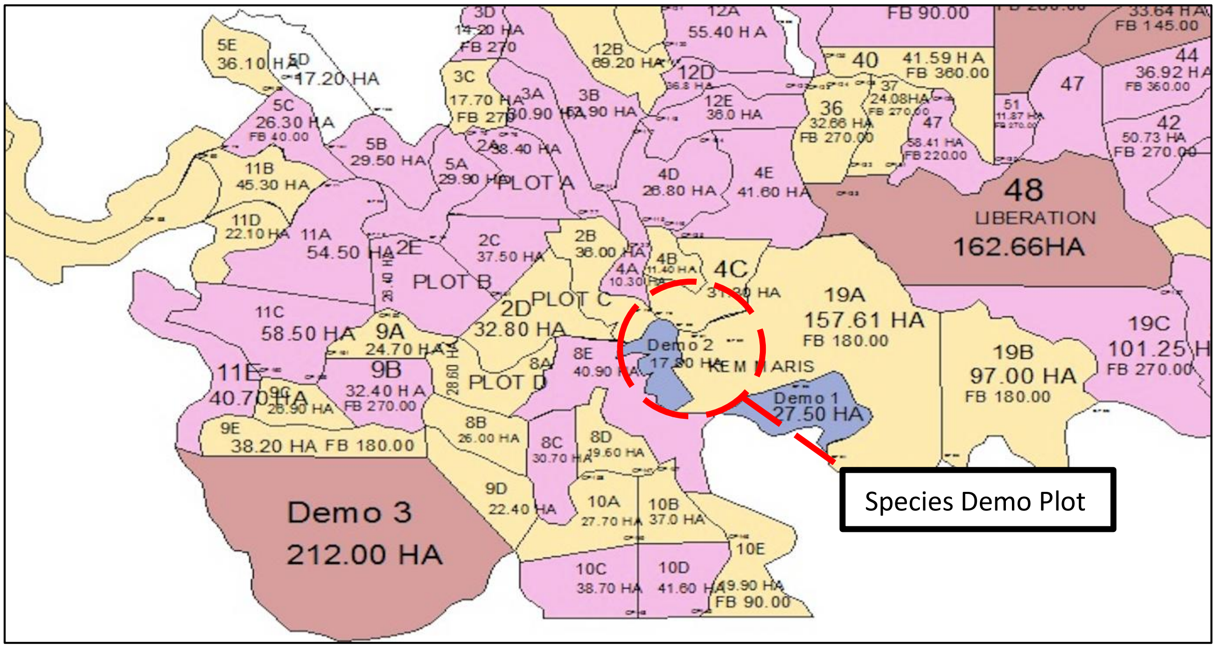

Figure 2. Location of the Species Demo Plot at the INIKEA Project site, Luasong, Tawau.

Experimental design

The complete randomized design (CRD) was applied in this study. Six tree species were chosen in this study, comprising three Dipterocarp and three non-Dipterocarp species which were each assigned with a code as listed in Table 1. Each species of tree was represented by four replicates. The replicates for each tree species were chosen according to its availability and accessibility at the site. The trees chosen were located randomly as illustrated in Figure 3.

No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Line																											
1	sdk	blim	d	ste	kmlm	kbk	tmp	ste	kddg	sbkt	mgga	tdb	ske	sdk	kddg	blm	umb	me	kbk	tmp							
2	ste	kbk	blm	sbkt	ske	sbbi	umb	x	x	x	me	blm	ste	tdh	slgi	x	kem	sdk	kmlm	x	x	x	tdb	os	ste	ste	tdb
3	kbk	meng	sp	skb	tdb	sbbi	x	x	x	tdh	kddg	skb	sbbi	slgi	x	lmku	umdl	os	sp	x	x	umb	sme	sbl	blm	tdh	
4	kpj	kpg	kmlm	kem	slgi	kwj	x	x	x	tmp	sdk	x	sksp	kddg	sdk	tmp	meng	umbt	kpg	kem	kpg	x	kddg	lmku	x	meng	
5	tdb	kbk	kbk	ske	kwj	os	sbbi	umbt	tmp	kmlm	kpg	ske	kpj	meng	meng	lmku	kmlm	skb	os	os							
6	kwj	kpj	kpg	sksp	slgi	x	kpj	sptir	kbk	tdh	mgga	sbbi	ske	sbl	d	kem	x	kddg	umbt	tdh	sksp	x	sp				
7	kbk	sbl	kbk	umdl	kddg	kbk	umb	meng	meng	blm	kpj	meng	tmp	kmlm	kddg	slgi	sbbi	tdh	sksp	sbbi							
8	me	tdb	sbkt	x	umdl	sksp	x	x	x	sp	me	x	smku	kem	kpg	smku	umdl	x	umdl	os	blm	sdk	tmp	x	x	bamb	kddg
9	d	d	ste	kddg	sptir	ske	umbt	x	kwj	ste	slgi	slgi	x	smku	ske	kpg	skb	mgga	sptir	sksp	me	kwj					
10	smku	kbk	sme	tdh	d	sbl	sbbi	smku	sdk	kem	ste	umbt	x	kddg	tmp	x	tmp	kwj	x	ste	smku	tdb	x	x	x	blm	
11	blm	kddg	skb	umdl	os	os	d	tdh	kbk	sbkt	sp	sdk	bamb	mgga	sbbi	slgi	umb	kpj	sbkt	sme							
12	skb	umbt	kpg	sbbi	d	ste	umbt	x	kwj	sbbi	tmp	os	lmku	d	lmkuc	x	tmp	smkuc	umbt	mgga	x	ske	tdb				
13	sbkt	sp	tdh	kpj	kddg	os	slgi	sptir	sksp	os	me	slgi	me	d	sdk	sbl	umdl	ske	tdh	skb							
14	smku	mgga	skb	d	blm	umdl	sdk	meng	kem	me	kpg	kmlm	x	umdl	kwj	ste	umdl	smku	umbt	kem	me						
15	kddg	meng	sbl	sksp	kem	skb	skb	x	sbl	kmlm	tmp	d	d	meng	tmp	meng	kpg	kmlm	slgi	umbt	kmlm						
16	sdk	sdk	kpj	bamb	umdl	bamb	lmku	kem	umdl	x	x	smku	tdh	sksp	me	blm	umdl	x	x	mgga	sptir	blm	skb	skb			
17	umdl	kem	ste	sbkt	lmku	sbl	tdh	sptir	umb	umbt	os	x	skb	sbkt	sbl	sp	sdk	sbl	sptir	bamb	kbk						
18	os	x	sp	skb	blm	bamb	x	umdl	kpj	os	sbl	kbk	tdb	bamb	sbkt	tdh	kmlm	me	os	x	kddg	x	tdh	meng			
19	lmku	meng	x	kpg	kpj	kem	tmp	bamb	os	tdb	skb	sbbi	umbt	d	sbl	ske	bamb	kem	umb	meng	slgi						
20	d	kpg	me	d	smku	kbk	kwj	mgga	kwj	umbt	slgi	x	sptir	x	skb	lmku	ste	umb	bamb	kddg	tdb	sbkt					
21	umb	kwj	kpj	sbkt	kwj	kmlm	tmp	me	ske	sptir	sme	umbt	x	x	x	x	x	x	x	x	kpj	kpg	mgga	os	sme	kmlm	kpj
22	mgga	kpj	sksp	sbbi	kpg	x	x	x	x	x	mgga	ske	me	sbbi	x	bamb	blm	kpg	kbk	tmp	ste	sbkt	tdb	x	umbt	kwj	umb
23	sdk	sksp	kmlm	kmlm	bamb	ske	x	tmp	sp	lmku	sbl	tdb	bamb	kwj	x	sksp	umdl	tdh	x	umb	umb	kmlm	umb				

Figure 3. Planting layout of trees at the Species Demo Plot and position of trees sampled (shaded in yellow).

Table 1. List of tree species sampled for defoliation symptom observation.

Family	Scientific name	Common name	Code
Dipterocarpaceae	*Dipterocarpus conformis*	Keruing Beludu Kuning	KBK
Dipterocarpaceae	*Dryobalanops lanceolata*	Kapur Paji	KPJ
Dipterocarpaceae	*Hopea ferruginea*	Selangan Mata Kucing	SMKU
Ebenaceae	*Diospyros* sp.	Kayu Malam	KMLM
Tiliaceae	*Pentace laxiflora*	Takalis Daun Halus	TDH
Tiliaceae	*Pentace adenophora*	Takalis Daun Bulat	TDB

Sampling Method

A one-time assessment was conducted at the Species Demo Plot for a period of six days on 15 until 20 July 2017. Age of trees that was assessed ranged between eight and ten years old, while the height of trees ranged between five and ten metres. Canopy of trees that was too high to access was reached by climbing a ladder. The tree canopy diameter ranged between two and three metres. Types of defoliation symptoms were recorded by assessing 30 leaves that were randomly chosen from the canopy of each individual tree. The number of defoliation symptoms observed on each leaf was recorded. The mean number of defoliation symptom type was calculated to represent the mean number of its occurrence on each species of tree. Pictures of each leaf chosen were also taken for record purposes.

Data Analysis

Chi-square analysis was conducted to determine whether there was any significant difference in the occurrence of defoliation symptoms recorded across the tree species.

RESULTS AND DISCUSSION

Types of defoliation symptoms according to category

Results for types of defoliation symptom percentage according to category are demonstrated in Figure 4. The defoliation symptoms observed in all the six species of trees were grouped into five categories, namely herbivory, egg cases, galls, leaf miners and leaf rollers. List of defoliation symptom occurrence is listed in Appendix 1.

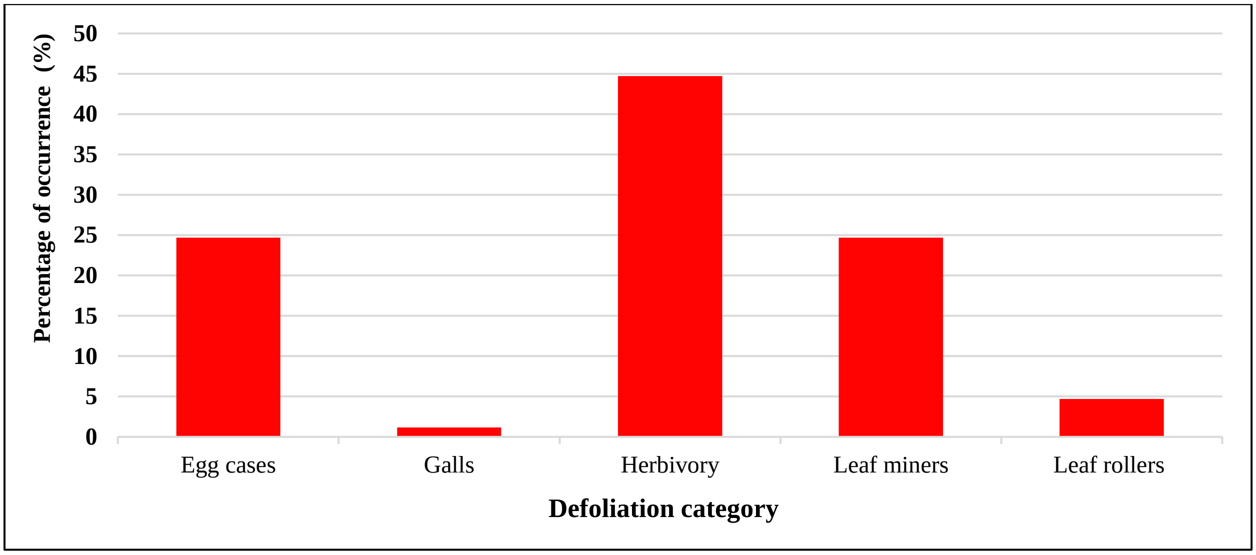

Figure 4. Percentage of defoliation symptom occurrence according to categories.

Results in Figure 4 show that the highest percentage of defoliation symptom recorded was herbivory, with 44.71% occurence. Common types of herbivory symptoms that were recorded include hole feeding (11 occurrences) and combination of free feeding and skeletonizing (9 occurrences). Based on the feeding patterns, herbivory was mostly caused by leaf-eating insects from the order Coleoptera, Lepidoptera and Orthoptera. In this study, hole feeding was the most common herbivory symptom recorded (Figure 6).

Meanwhile, egg cases (Figure 7) and leaf miners (Figure 8) each recorded the same percentage of occurrence, which was 24.71%. Egg case symptoms comprised any egg cases and egg shells that were still intact on the leaf surface, twig or branch of the trees. In this study, egg cases were commonly observed both either on the leaf surface or underneath the leaf surface. As for leaf miner category, the common leaf miner symptoms observed include the straight-line miners (4 occurrences) and tiny-skruggle miners (4 occurrences). While the least or most rare type of symptoms were leaf rollers (4.71%), where there were only two types encountered (sideway roller/folder and wrinkle) and galls (1.18%), which was only encountered once in *H. ferruginea*.

Comparison of mean defoliation symptom occurrence between tree species

The mean defoliation symptom occurrence between six tree species was compared as illustrated in Figure 4. The highest total mean defoliation symptom occurrence was recorded in *D. lanceolata*, with a total mean of 4.75 occurrences, followed by a total mean of 3.75 recorded in *D. conformis*. Meanwhile, the lowest total mean defoliation was recorded in both *H. ferruginea* and *Diospyros* sp. with a mean of 3.00 in each species.

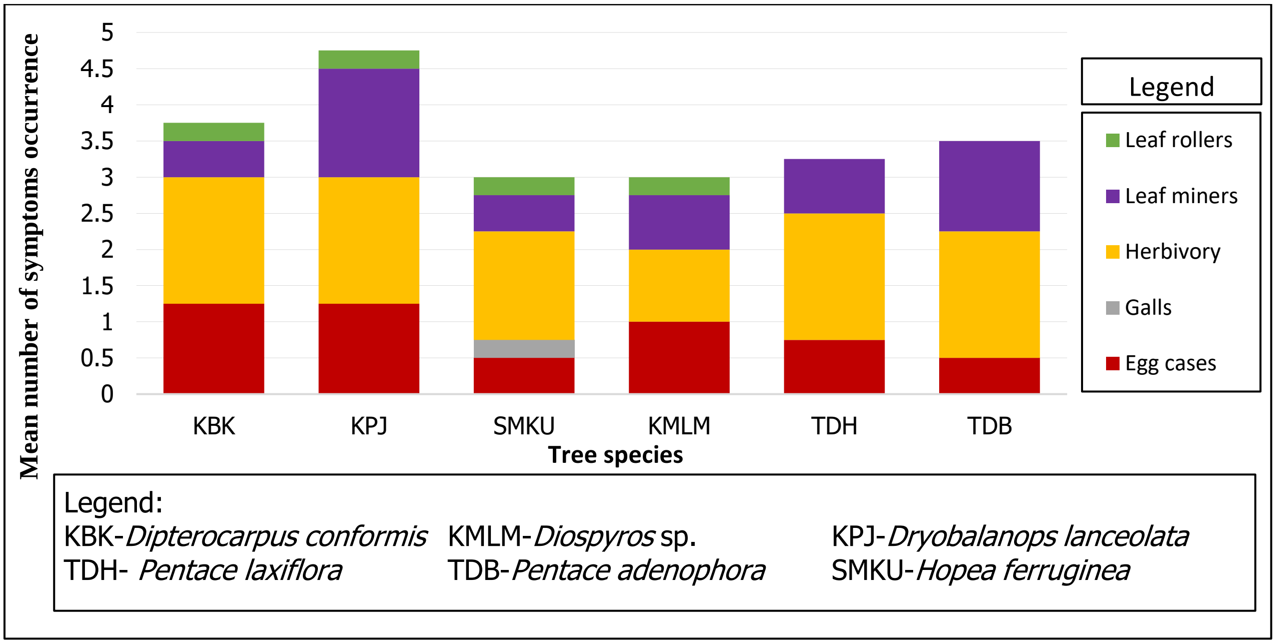

Figure 5. Comparison of total mean defoliation symptom occurrence and types of defoliation according to tree species.

Results in Figure 5 show that herbivory occurred in all tree species and was the highest recorded defoliation symptom compared to other categories. Herbivory occurrence was highly recorded in *D. conformis*, *D. lanceolata*, *P. laxiflora* and *P. adenophora* with a similar mean of occurrence which was 1.75 in each species.

Other defoliation symptoms that were also recorded across all the tree species were egg cases and leaf miners. The egg cases symptoms were highly recorded in both *D. lanceolata and D. conformis* with the mean of 1.25 occurrence in each of the tree species.

The existence of leaf miners on the other hand, was the highest in *D. lanceolata* with a mean occurrence of 1.5, followed by *P. adenophora* and was the lowest in *H. ferruginea*. In contrast, leaf rollers were only recorded in *D. conformis*, *D. lanceolata*, *H. ferruginea* and *Diospyros* sp. with a mean occurrence of 0.25 for each species of tree.

Interestingly, the occurrence of galls was only recorded on *H. ferruginea* leaves. This could be related to specialized feeding habits of gall inducing insects, such as Homoptera, Diptera and Hymenoptera. These insect groups are usually confined to specific host plants (Shorthouse *et al*. 2005). Hence, insects causing galls were probably host specific to only *H. ferruginea*. Similar result was also recorded by Hosaka *et al.* (2009) in which they found galls in different forms were restricted to a single host species of dipterocarp.

The results from this study showed that defoliation symptom occurrence varied among tree species. Similar findings were also reported by Paul *et al.* (2012). In general, different tree species has different leaf traits which may influence the feeding preference of herbivorous insects towards the plants. Therefore, variation of leaf traits, such as carbon and nitrogen content, specific leaf area and leaf toughness across the tree species may influence the existence of defoliation in each tree species (Coley & Barone 1996, Paul *et al*. 2012).

The Chi-square analysis showed no significant difference in the total occurrence of defoliation symptoms across all trees species (p>0.05), as shown in Table 2.

Table 2. Chi-square analysis result.

	Chi square (X^2)	**Df**	**Sig.**
Tree species	36.709	30	.534

As the Species Demo Plot consists of mixed tree species, occurrence of defoliation symptoms was not distinct between tree species. This explains that the occurrence of defoliation symptoms was not dependent on the tree species. Furthermore, there is a possibility that the defoliation symptoms recorded in this study were caused by generalist insects. It is because a forest with multiple tree species may consist of more generalist insects compared to specialist insects (Novotny *et al.* 2002). The presence of specialist insects is suppressed due to the diversity of tree species in the area that caused declining availability of resources and encounter rates between herbivores and hosts (Kambach *et al*. 2016). Hence, it will subsequently limit the availability of host trees for specialist herbivores.

CONCLUSION

In conclusion, there was a variation of defoliation symptoms recorded for all six tree species planted at the Species Demo Plot. The highest percentage of defoliation symptom category was herbivory (44.71%), followed by both egg cases and leaf miner (24.71% respectively) and the lowest defoliation symptom category was galls (1.18%). The mean defoliation symptom occurrence was highest in *D. lanceolata* with 4.75 occurrences, while the lowest mean defoliation symptom occurrence was recorded in both *Diospyros* sp. and *H. ferruginea* with a mean of 3.00 occurrences in each of the species. The Chi-square analysis result showed no significant difference (p>0.05) in the total occurrence of defoliation symptoms across the trees sampled.

The results from this study can be helpful towards identifying different defoliation symptoms that can be found on the canopy of trees planted in restoration area. In addition, the existence of the defoliation symptoms found in this study can give an early indication on a positive diversity recovery of insects in a restoration site.

ACKNOWLEDGEMENTS

This project was funded by the Kamprad Family Foundation, project code (GL-00158). The authors would like to thank the Yayasan Sabah Foundation for the permission to conduct this study at the Species Demo Plot, Luasong and Mr. David Alloysius for providing necessary information of the study site and for facilitating our stay in Luasong. Appreciation also goes to the research assistant, for providing assistance during the data collection. Lastly, special thanks to fellow colleagues from Forestry Complex, Faculty of Science and Natural Resources, UMS for the support and guidance rendered throughout this project.

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Appendix 1. Checklist of defoliation symptoms according to categories.

Category	**Type of symptoms**	**KBK**	**KPJ**	**SMKU**	**KMLM**	**TDH**	**TDB**	**Total**
Egg cases	Black	1	0	0	0	0	1	2
Egg cases	Black case	0	0	0	0	1	0	1
Egg cases	Black case with silk	0	1	0	0	0	0	1
Egg cases	Black egg case	0	0	1	0	0	0	1
Egg cases	Orange egg cases	1	0	0	1	0	0	2
Egg cases	Plaster seal against main vain	0	0	1	0	0	0	1
Egg cases	Silk with fibre	1	1	0	0	0	0	2
Egg cases	Three silk thing	0	0	0	2	0	0	2
Egg cases	White	0	1	0	0	0	0	1
Egg cases	White circular	0	0	0	0	1	0	1
Egg cases	White long	0	1	0	0	0	0	1
Egg cases	white with wispy web	1	1	0	1	1	0	**4***
Egg cases	Whitish silk nest like	0	0	0	0	0	1	1
Egg cases	Yellowish egg sac	1	0	0	0	0	0	1
Galls	Interior	0	0	1	0	0	0	1
Herbivory	Combination	1	1	2	1	2	2	**9***
Herbivory	Dots due pierce and sucking	2	0	0	0	1	0	3
Herbivory	Edge/margin	1	1	2	0	0	0	4
Herbivory	Free feeding	2	0	0	2	0	0	4
Herbivory	Hole feeding	0	3	1	1	2	4	**11***
Herbivory	Pinhole	0	1	0	0	1	0	2
Herbivory	Rough cut	0	0	0	0	0	1	1
Herbivory	Interior	1	1	1	0	1	0	4
Leaf miners	Large miner	1	0	1	0	0	1	3
Leaf miners	Miner	0	0	0	2	0	0	2
Leaf miners	Rough cut skruggle-miner	1	1	0	0	0	0	2
Leaf miners	Skruggle	0	0	0	0	0	1	1
Leaf miners	Small miner	0	2	1	0	0	0	3
Leaf miners	Small miner plus hole feeding	0	1	0	0	0	1	2
Leaf miners	Straight line miner	0	1	0	0	2	1	**4***
Leaf miners	Tiny skruggle-miner	0	1	0	1	1	1	**4***
Leaf rollers	Sideway roller/folder	1	1	1	0	0	0	**3***
Leaf rollers	Wrinkle	0	0	0	1	0	0	**1***

*****Common defoliation symptom recorded.

Appendix 2. Examples of defoliation symptoms observed.

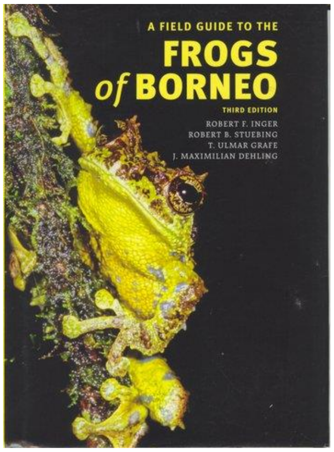
Figure 6. Example of herbivory: hole feeding symptom recorded on TDB (*Pentace adenophora*) leaves.

Figure 7. Example of egg case found on the leaf surface of KBK (*Dipterocarpus conformis)*.

Figure 8. Example of common leaf miner found on leaf of TDH (*Pentace laxiflora*).

Figure 9. Example of leaf rollers of KBK (*Dipterocarpus conformis)*.

Figure 10. Galls on the leaf surface of SMKU (*Hopea ferruginea*).



A Field Guide to the Frogs of Borneo *(3rd Edition)* Authors: Robert F. Inger, Robert B. Steubing, T. Ulmar Grafe & I. Maximillian Dehling. Pp 228. ISBN 978-983-812-176-7.

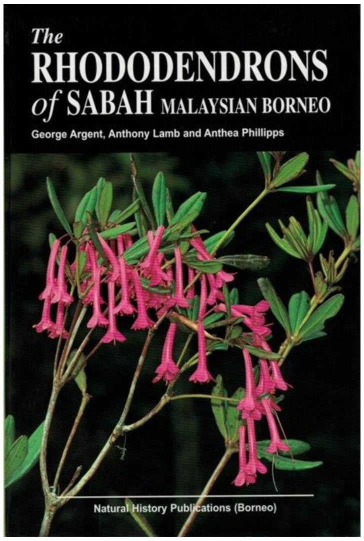
Reviewed by E. Khoo

Since its establishment in 1992, the Natural History Publications (Borneo) Sdn. Bhd. has become one of the leading book publishers in South East Asia, known for its publications ranging across different genres in relation to the Island of Borneo.

One of its latest publications is a Field Guide to the Frogs of Borneo (3rd Edition). Aside from the two famous names in Borneo's herpetology studies (Robert F. Inger and Robert B. Steubing, authors for the first two editions), the 3rd edition is greatly enriched with the involvement of T. Ulmar Grafe and I. Maximillian Dehling, where both have contributed significantly in this field as well.

Overall the book is beautifully written where the language used is that of narrative format, thus bringing the subject to life. The authors took time in laying down the foundational understanding of the group in terms of its biology, ecology, distribution & classification, conservation and its role in human tradition and culture before moving on to provide species accounts for 8 families, encompassing 183 species. The accounts started off with information, such as distribution range for each family followed by species identification keys. Descriptions at the species level have included information, such as different features of adult and tadpole, habits and habitat, calls and species distribution within Borneo.

The book would be appealing to non specialist as the information it contains was written in a language that is easy to understand, especially for those who are interested to try their hands in species identification. Two notable aids that will further enhance the identification process are the high resolution photographs and the frogs' call recordings. Authors (T.U. Grafe and I.M. Dehling) have compiled a list of frog species' calls recording that is made accessible through www.soundcloud.com/frogvoicesofborneo, thus bringing the call descriptions to life. Although some of the species' information has yet to be completed, as put forth by the authors: "*The number of new species continues to rise, and we can only guess how many more remain to be found*.", therefore within the herpetology field, there remain knowledge gaps to be filled and discovered.



The Rhododendrons of Sabah, Malaysian Borneo by George Argent, Anthony Lamb & Anthea Phillipps. Published by Natural History Publications (Borneo), Kota Kinabalu, 2007. Pp 280. ISBN 983-812-111-8.

Reviewed by E.B. Johnlee

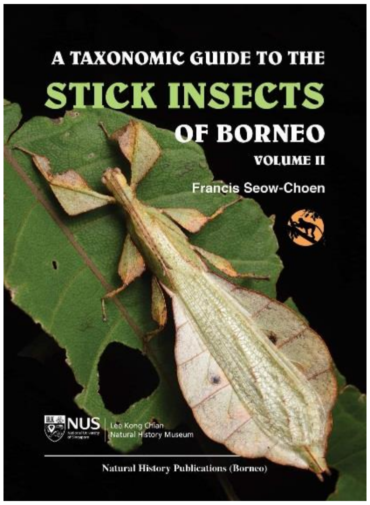
Everyone, including little children will probably know of a classic tale called Beauty and The Beast. This tale was made into a movie in 2017 and instantly became popular. The enchanted rose was my favourite part of the movie, the beast must learn to love one another, and earn love in return by the time the last rose petal fell, then the spell will be broken and the beast will turn back into human. There are power, magic and mystery surrounding the enchanted rose. As I first read about Rhododendrons in this book, I couldn't help but be reminded of the enchanted rose, in which Rhododendron is also known as the rose tree. "Rhodon" is Greek word for "rose" and "Dendron" for "tree". One could call Rhododendrons, the enchanted roses of Sabah because of their large showy flowers, sometimes beautifully scented, and it is well known and much cultivated in many parts of the world.

A famous poet once said, "Colour is a power which directly influences the soul", which I couldn't agree more as I flipped through the pages of this book which are filled with wonderful pictures and illustrations of the colourful and beautiful Rhododendrons. Rhododendrons are a wonder to behold, unique and they look stunning, even more so as you read through the detail descriptions of each part of the Rhododendrons by the authors in the introduction, from the types of scales, leaves, flower buds, fruit capsules, pollen and pollinators and the list goes on. Indeed the Rhododendrons have an interesting biological "life style" which you will find out once you read through the publication. In the publication, the authors has also provided details on Rhododendrons in the different vegetation types across different mountain ranges in Sabah, an overview of the distribution of Rhododendrons in Sabah and keys to Sabah Rhododendrons and even notes for guidance in using the keys. Many aspects of Rhododendrons' biology are poorly known and this publication proves to be useful as a guide for identification, promoting further research into the biology of Rhododendrons and raises interest of people to study Rhododendrons.

In conclusion, this book is definitely a must have collection for Rhododendron enthusiasts, botanists, and other group of researchers, be it as a personal collection, as a library collection or even as a gift to encourage and inspire people's interest on Rhododendrons.

"Nature is painting for us, day after day, pictures of infinite beauty."

John Ruskin



A taxonomic guide to the Stick Insects of Borneo Volume II by Francis Seow-Choen. Published by Natural History Publications (Borneo) Sdn. Bhd. in association with Lee Kong Chian Natural History Museum, 2017. Pp. 261. ISBN 978-983-812-177-4.

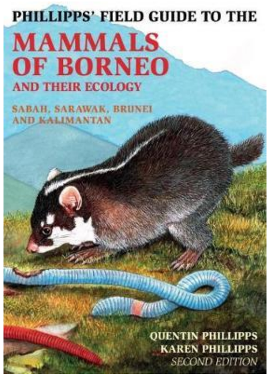
Reviewed by V. Paul

The book is the follow up to the author's first volume of a Taxonomic Guide to the Stick Insects of Borneo. As for this book, the author concentrates on the insects that can be found in Mount Trusmadi, the second highest mountain in Borneo after Mount Kinabalu. The study of the entomological collections at Kinabalu Park and Forest Research Centre, Sepilok is also included in this book.

This book features new genera and species, highlighting many phasmids from Mount Trusmadi. Through this study, the author provided details on 373 Bornean species and subspecies from 92 genera. Volume II highlighted the description of 4 new genera, 1 genus new to Borneo, 37 new species, 4 new name combinations, 3 new synonyms, 2 wrong synonyms and 9 descriptions of the previously unknown sex of known species.

What first amazed you about the book is its lavishly vivid photos of stick insects. Images and graphics that are incredibly presented in this book give readers a glimpse of the richness of stick insect's families and genera that can be found in Borneo. Thus, you will be fascinated with the photos of stick insects in your reading. The wonderful presentation of this book is that each species is described with details on its taxonomy, measurement, locality and etymology. In some species, the foodplants are also included. In my opinion, it would be even better if the author showcases the development and growth stage of the stick insect in general. Stick insects are part of the hemimetabola group of insects; this means that they do not undergo a complete metamorphosis. So, it would be good to have additional information on this. The terminologies used in the description part may be complicated for a light reader to understand, but they are featured in Volume I of the book. With the book's side tabs, perhaps it will be easier for readers to directly refer to the page of preferences for certain families of stick insects.

Overall, this comprehensive book provides pertinent information on stick insects that can be found in Borneo. The book is suitable for the use of entomologists, especially stick insect specialists, academicians and researchers, students and other parties or individuals who have a passion for stick insects. We in Borneo indeed appreciate, and are thankful to Dr. Francis Seow-Choen for his invaluable contribution in producing this comprehensive, useful and beautifully-presented book of stick insects.



Phillipps' Field Guide to the Mammals of Borneo and their Ecology by Quentin Phillipps & Karen Phillipps. Published by John Beaufoy Publishing, England, 2018. Pp 400. ISBN 978-1-912081-95-0.

Reviewed by M.A.F. Suis

Once again, they have made it! This second edition of the Mammals of Borneo field guide offers updated information and illustrations of mammal species found in Borneo. Although the focus is supposedly on mammals and their ecology, this field guide also covers various crucial topics, such as climate, origin and evolution of Bornean mammals, and also plants.

The information provided for each mammal is comprehensive. For a majority of the mammals, this field guide describes their taxonomy, endemism status, habitat, key morphology and species range. Readers would also not fail to notice that the illustrations of species were well-delivered and hence, is of great help when used as a guide in the field. For certain species, their interactions with plants were also emphasized in detail.

This 400-page field guide also listed out several threats of the Bornean mammals. As it includes 247 species of Bornean land mammals, this field guide is recommended for environmentalists, students and even tourists.

"*Like us, animals feel love, joy, fear and pain, but they cannot grasp the spoken word. It is our obligation to speak on their behalf ensuring their well-being and lives are respected and protected.*"

Sylvia Dolson

GUIDE TO CONTRIBUTORS

Sepilok Bulletin is a biannual peer-reviewed journal published by the Forest Research Centre of the Sabah Forestry Department. The Bulletin publishes manuscripts addressing subjects related to tropical forestry, in Borneo and elsewhere. Manuscripts may be in the form of original research papers, short communications, review articles, monographs, book reviews, and announcements.

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In the list of references, the papers should be arranged alphabetically by authors' names, and chronologically per author, and conform to the following format. All citations in the text should be listed, and all papers listed should have been cited.

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REPRINTS

On publication, 25 reprints will be supplied free to the author(s).

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Front cover: Leafy twig of *Ternstroemia aneura*, the most common species of the genus in Borneo. (Photo: Suzana Sabran)